UNCLASSIFIED

RESTRICTED

AR-001-650

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

ELECTRONICS RESEARCH LABORATORY

TECHNICAL REPORT

JINDALEE PAPER NO. 134

PROJECT JINDALEE: THE HF ENVIRONMENT AT ALICE SPRINGS, 1977-1978

B.D. Ward

S U M M A R Y

(U) This report is concerned with the HF radio environment at Alice Springs. It examines the background atmospheric noise levels, distribution of signals and their strengths, and availability of radar clear channels at Alice Springs during the Jindalee Stage A experimental program.

POSTAL ADDRESS: Director, Electronics Research Laboratory,
Box 2151, GPO, Adelaide, South Australia, 5001.

~~RESTRICTED~~

UNCLASSIFIED

TABLE OF CONTENTS

LIST OF FIGURES

36. Mean power in a 10 kHz bandwidth: 6 to 10 MHz

37. Mean power in a 10 kHz bandwidth: 10 to 15 MHz

38. Mean power in a 10 kHz bandwidth: 15 to 20 MHz

39. Mean power in a 10 kHz bandwidth: 20 to 30 MHz

40(a). Range of noise values measured over a one month period

40(b). Range of noise values measured over a one month period for hours of radar operation only

41. Losses in the modified system

42(a). Range of noise values measured over a one month period using the modified system

42(b). As in (a) but for hours of radar operation only

43. Minimum noise levels expected during Stage B radar operations

1. INTRODUCTION

(U) An important factor in the performance of an Over-the-Horizon (OTH) radar is the nature of the HF signal environment in which the radar must operate. There are a number of different features of the signal environment which are of interest in the design and implementation of such a radar. The receiver designer, for example, will be interested in the background noise levels as a function of frequency and time of day, as well as the distribution of large signals which will place demands on various aspects of the antenna and receiver design. Satisfactory operation of the radar will be dependent on algorithms which select a channel which is clear of interference and which will offer the best signal-to-noise ratio possible.

(U) The Jindalee Stage A equipment(ref.1) included the radar system and an environmental data logger. The data logger(ref.2) contained an ionospheric backscatter sounder and an HF surveillance system, and provided real-time frequency management advice to the radar as required. Unlike the radar, the data logger operated continuously and recorded a detailed data base of measurements of the HF signal environment over the entire 24 hour period for nearly 2 years. This report summarises those features of the HF environment measured by the surveillance system at Alice Springs during the period March 1977 to December 1978.

2. SURVEILLANCE DATA BASE

(U) The surveillance system provided calibrated measurements within the HF spectrum between 6 and 30 MHz with a resolution of 2 kHz. Routine observations were recorded automatically on a regular basis with a complete scan of the spectrum taking 15 min to complete. Since the surveillance system alternated with the backscatter sounder, scans of the HF spectrum were obtained approximately once every 30 min, alternately using an omnidirectional whip antenna and a highly directional beam from the Stage A radar antenna system. In this report this directional beam will be referred to as the +3° beam, as defined in reference 1. The data on which this report is based consists of approximately one complete scan from 6 to 30 MHz on each antenna per hour from October 1977 to December 1978. Data are also used prior to October 1977 where measurements were carried out using only the whip antenna.

(U) Output from the receiver was digitised and processed using 4096-point Fast Fourier Transforms (FFT's). The raw resolution after processing was 200 Hz and 10 spectral estimates were averaged to provide stable measurements of the spectral density with 2 kHz resolution. Each 1 MHz segment of the spectrum was scanned 10 times and the average, maximum and minimum values for each of the five hundred, 2 kHz measurements within the 1 MHz segment were recorded on magnetic tape. A calibration system was used to convert the measurements to absolute units (dBW/2 kHz) before the data was recorded on magnetic tape. The calibration factor was also recorded on magnetic tape and subsequent analysis revealed that the receiver gain stayed constant to within 1 dB over the entire data collection period.

(U) Detailed analysis of the surveillance data has shown(ref.3) that the only significant source of contamination of the data resulting from receiver limitations was due to out-of-band intermodulation distortion (IMD). The effects of IMD were particularly severe in data obtained from the directional radar beam since this included a preamplifier with 30 dB gain in front of the

receiver, whereas the omnidirectional whip antenna was connected directly to the surveillance receiver. Those data which have been affected by IMD products are noted in the subsequent sections of this report. A set of switched filters were introduced into the system in September 1978 and provided a significant improvement.

(U) The other limiting feature of the surveillance system was the fact that it was always internally noise-limited above 20 MHz, and was internally noise-limited during the day below 9 MHz. Again, these effects will be pointed out where they affect the interpretation of the data. An attempt was made to rectify this situation with the addition of a 20 dB gain preamplifier between the whip and surveillance receiver and the results of this modification are also discussed in this report.

3. ATMOSPHERIC NOISE LEVELS

3.1 Measurement technique

(U) One of the fundamental characteristics which is of importance to the designer of an HF radar, or of any HF communications system, is the background atmospheric noise level at the frequencies of interest. The conventional method used to measure the background noise level at a given frequency is to tune to an interference-free channel and to record the noise level at that frequency over a period of time. Although the surveillance system incorporated a routine which measured the noise level in nominally clear channels at 0.5 MHz intervals, analysis revealed that this data was of limited usefulness. Prior to May 1978 the clear channel algorithm was not sufficiently sensitive and the spot-frequency data was frequently contaminated by discrete RF signals. Subsequent to the introduction of a more stringent clear channel algorithm in May 1978 the spot frequency measurements were more reliable but still subject to certain limitations.

(U) Analysis has shown that an alternative method can be adopted to measure the background atmospheric noise levels from the surveillance data. Since atmospheric noise does not vary strongly with frequency over a 0.5 MHz segment of the spectrum(ref.4), the median of the 250 measurements made by the surveillance system of the spectrum would, in the absence of any discrete RF signals, represent a reliable estimate of the background noise level. As the number of discrete signals increases the median becomes contaminated and overestimates the background noise level. The lower decile of the 250 measurements is not affected to the same extent and analysis of the data has shown that it provides a reliable measurement of the background noise level. Figure 1 shows a portion of the HF spectrum which includes a moderate number of large signals and which illustrates the distortion of the median by discrete RF signals. Dynamic range limitations in the data recording and processing resulted(ref.3) in an artificial elevation of the noise floor in the broadcast bands in the presence of very large signals as can be seen in figure 2. Consequently the broadcast bands were eliminated from the surveillance data used to determine the background noise level at 0.5 MHz intervals.

3.2 Omnidirectional antenna

(U) The data published in CCIR Report 322(ref.4) is commonly used to estimate the atmospheric noise levels at HF for any given receiving location. The predictions given in that report are for a short loss-less vertical antenna over a perfectly conducting ground-plane. The whip antenna used in the Stage A surveillance system was physically similar to that used for the CCIR measurements and analysis (Sinnott, private communication) has shown that the vertical radiation pattern of the two antennas was similar. The noise data measured on the whip antenna have been corrected for losses in the system to allow comparison with the CCIR predictions for Alice Springs. This correction, shown in figure 3, corrects for mismatch loss between the whip and the cable, attenuation in the 193M cable between the whip and the receiver and the ground loss of the whip antenna.

(U) The diurnal variation of atmospheric noise as measured on an omnidirectional whip antenna is shown in figures 4 to 9 for frequencies between 6 and 17 MHz. As was noted previously, the surveillance system was internally noise limited below 9 MHz during the middle of the day and was always internally noise limited above 20 MHz. The solid line in these figures is the predicted noise level derived from CCIR Report 322, generated using a mathematical model of the data presented in Report 322(ref.5). The noise data published in CCIR Report 322 is in the form of world-wide atmospheric noise maps for a frequency of 1 MHz and in four-hour time blocks, together with graphs of the frequency dependence of the atmospheric noise. Lucas and Harper(ref.8) used these maps to generate, by means of a least-squares fit based on Fourier analysis, numerical coefficients representing the world-wide distribution of atmospheric noise as a function of geographic location. The frequency dependence of atmospheric noise was generated from a power series of least-squares fit and values for a given time of day were interpolated from the two adjacent four-hour time blocks.

(U) Although the atmospheric noise levels are in approximate agreement with the CCIR predictions for Alice Springs there are a number of significant differences. The best agreement between the observations and the predictions was found in December 1977 (ie Summer) when the general diurnal trend was adequately predicted by the CCIR model. There is however a significant difference between the actual levels predicted and those observed. At first sight inspection of figure 6 would suggest the possibility of a constant error, independent of frequency, in the correction factors applied to the whip data. However, in view of the fact that data for other months shown in figures 4 to 9 reveal that there was no constant difference between the predicted and observed levels, and since the receiver gain was known to have remained constant over the entire data recording period, it seems unlikely that the disagreement between the predicted and observed levels in December 1977 could be explained in this way. During the summer months the CCIR model consistently overestimated the atmospheric noise levels measured during the daylight hours at frequencies below 12 MHz, and overestimated the levels at most times of the day above 12 MHz. The model also underestimated the rate at which the noise levels decreased at sunrise compared to the more gradual increase associated with sunset.

(U) Another major difference between the CCIR predictions and the observations is the extent of seasonal effects on the atmospheric noise levels. Although there are differences between the data recorded in 1977 and 1978, most notably between 10 and 13 MHz, there appears to be little difference in the diurnal variation of the noise level from March through to September of each year. The CCIR model predicts a significant seasonal change in the diurnal variation which is not reflected in the observations. This is most notable during winter where figures 4 and 8 show that there was a diurnal variation in the noise level up to 14 MHz while the CCIR model predicts little diurnal variation above 9 MHz.

(U) Another feature which was particularly evident during 1977, and to a lesser extent during 1978, was marked variations in the atmospheric noise levels over a timescale of several hours. These variations were consistent from day to day, the most significant occurring around sunrise. The possibility of instrumental effects arising from strong broadcast band signals contributing to this data has not been entirely ruled out although the analysis to date has not revealed the source of any such effect.

(U) An alternative comparison between the observations and the CCIR predictions is given in figures 10 to 13 where the variation of the noise level as a function of frequency is plotted for a number of times of day. The most significant feature of these plots is the fact that in the period 1800 to 0700 L.T. the variation with frequency is somewhat steeper than predicted, and between 0800 and 1500 L.T. the CCIR model more or less consistently overestimates the noise level between 6 and 17 MHz.

3.3 Directional antenna

(U) Atmospheric noise measurements made on the directional radar beam are presented in figures 14 to 17. The levels shown are those measured at the receiver input with no correction factors applied. The total correction factor for losses in the Stage A radar receiving antenna, equivalent to those shown in figure 3 for the whip antenna, have been calculated by Earl(ref.9). Figure 18 shows this correction factor for the +3° beam both prior to and following the installation of adaptive beamforming outputs in July 1978. It should be noted that the correction factor has been calculated assuming an isotropic noise source, so that directional effects in the noise and the antenna are not taken into account except in so far as the isotropic assumption is valid.

(U) Below 13 MHz there is broad agreement between the noise levels measured on the whip antenna and those measured on the directional antenna which is independent of season. There is some evidence of an anisotropic distribution of noise, though this is not surprising since the directional beam was pointed towards a region which has a high incidence of tropical thunderstorms. The extent of the anisotropy has not so far been assessed.

(U) Above 13 MHz there is evidence that the results between 1800 and 0700 L.T. are corrupted by out-of-band IMD products arising from very strong signals in the 7, 9, 11, 15 and 17 MHz broadcast bands. A more detailed analysis of these effects is presented in reference 6. The effect of a significant number of IMD products is to corrupt the receiver output to such an extent that the background noise level is never measured as can be seen in figure 19. The system was known to be internally noise limited above 20 MHz. Consequently the true noise levels above 20 MHz were

-194 dBW/Hz at all times, as determined by the internal noise figure of the surveillance receiver.

(U) The wide scatter in the noise measurements above 20 MHz between 1800 L.T. and 0700 L.T. is the result of very large numbers of IMD products. A set of switchable filters were installed in front of the receiver in September 1978. The effect of these filters was to dramatically improve the IMD performance, especially above 18 MHz as can be seen in figure 20. However, there is a suggestion that there was still a degree of contamination between 14 and 17 MHz due to third-order out-of-band IMD products. This can be seen in figure 20 between 02 to 04 L.T., for example, where there is a significant decrease in the scatter of the data above 18 MHz. This coincides with the introduction of an 18 MHz high pass filter in front of the receiver. A 12 MHz high pass filter was also used for measurements in the range 12 to 18 MHz but the roll-off of this filter was insufficient to prevent 7, 9 and 11 MHz broadcast band stations combining with 15 and 17 MHz broadcast band stations to provide third-order products in the range 12 to 18 MHz.

4. LARGE SIGNAL ENVIRONMENT

(U) Another feature which is of interest in the design of an HF radar is the large signal environment in which the radar must operate. Since the HF spectrum is subdivided into a number of bands which are allocated to different services it could be expected that there would be some variations in the magnitude and distribution of large signals from band to band. Figures 21 to 24 illustrate the range of signal levels which have been measured over a typical month. The levels shown are those measured at the input to the surveillance receiver. To convert these to the values at the whip antenna it is necessary to add the correction factor shown in figure 3 to account for losses in the system.

(U) Figures 21 to 24 show the distribution of signals within each service allocation band plotted as the percentage of 2 kHz channels within the band which have a signal strength less than a given value. One curve is plotted for each surveillance observation (approximately one measurement each hour) and the data plotted covers a one-month period.

(U) The large spread in these curves reflects the changes in propagation conditions as a function of time of day. At low frequencies the largest signals are measured in the night time since low frequencies are heavily attenuated during the day, whereas at high frequencies signals are not propagated during the night and the largest signals are recorded during the day. As could be expected the broadcast bands possess the greatest percentage of large signals, although there are also a number of strong signals in the fixed service bands. Some of these signals are in fact braodcast stations operating outside of, but adjacent to, the international broadcast bands. The most consistent example is Radio Peking on 7380 kHz which is responsible for the signal at -70 dBW/2 kHz in the 7300 to 8195 kHz band in figure 21.

(U) The large diurnal variation which contributes to the spread of values in figures 21 to 24 masks the dynamic range which is likely to be required for simultaneous measurement of both the atmospheric noise level and the largest discrete signals. Figures 25 to 28 show the distribution of the dynamic range (that is, signal level-background noise level) over a one month period. Much

of the spread in this data again results from the diurnal variation. These results show that the most demanding conditions apply in the broadcast bands, particularly at 7, 9, 11, 15 and 17 MHz. Above 20 MHz large portions of the spectrum are free from large signals. At lower frequencies the aeronautical and maritime bands have a lower percentage of large signals than do those bands allocated to fixed stations.

(U) The only significant difference between the distribution of large signals measured on the omnidirectional whip antenna and those measured on the directional radar beam is to be found in the broadcast bands where there were always considerably more strong signals measured with the directional antenna. This can be attributed to European and Asian (particularly India and Pakistan) broadcast stations transmitting programs for reception in the South Pacific region and to the directional gain afforded by the radar beam.

5. RADAR CLEAR CHANNELS

5.1 Channel availability

(R) Satisfactory operation of an HF radar is dependent on the selection of a suitable operating frequency which is free from interference. The design of a suitable algorithm for locating "clear" channels from the surveillance data must not only select the channel with the lowest noise level but must also attempt to ensure that the channel is likely to remain clear. Three questions must therefore be addressed:

(1) how often must the spectrum be scanned to determine, with a certain degree of confidence, that a given channel is "clear"?

(2) what is the probability of finding a "clear" channel?

(3) having found a clear channel what is the likelihood that the channel will remain clear?

These questions cannot be completely answered by analysis of the Stage A data because of the coarse time resolution of the observations.

(R) Before it is possible to determine the probability of finding a "clear" channel some definition must be adopted to define what is meant by a clear channel. Ideally the radar would operate in a channel which possessed a noise level as close to the background atmospheric noise level as possible. During Stage A operations the clear channel algorithm started with a threshold which was equal to the background noise level over a 1 MHz segment of the spectrum and the threshold was then incremented until at least five 10 kHz channels were available within each megahertz, as is illustrated in figure 29.

(R) Since this algorithm would appear to offer a simple method or determining nominally clear channels it has been adopted here with one slight modification in that the algorithm was chosen to find those thresholds which would provide 2 clear channels over each 0.5 MHz segment of the HF spectrum. The important question is then - how many decibels must the threshold be raised above the background noise level in order to find 2 channels per 0.5 MHz? Figures 30 and 31 show the thresholds in decibels above background noise levels which are required to obtain 2 clear

channels, of 10 kHz bandwidth, per 0.5 MHz for January and July 1978. The values plotted are the average thresholds, over a 10 day period within each month, for the given time ranges indicated. They represent the average of approximately 150 observations. Analysis of such data reveals that there is no significant change from month tc month. The horizontal bars indicate the frequencies of interest to an OTH radar scanning ranges between 1000 and 3000 km as predicted in reference 7.

(R) In general it is almost always possible to find 10 kHz wide clear channels within a few decibels of the background noise level. The most difficult period is at low frequencies at night time when most users of the spectrum crowd down into the region below about 12 MHz. However even when particularly difficult conditions existed analysis has shown that it was always possible to find one or two 4 kHz channels per 0.5 MHz which were within 5 dB of the background noise level.

(R) As the bandwidth required for radar operation is increased the problem becomes more difficult. Figure 32 shows the thresholds required to find two 20 kHz wide channels per 0.5 MHz during winter while figure 33 shows the threshold required to find two 40 kHz wide channels during winter. Similar distributions apply during the other seasons.

5.2 Temporal variations

(R) It is important that not only should the selected channel be as close as possible to the background noise level but there should be some confidence that the channel will remain clear. Figure 34 shows the distribution of clear channels from 14 to 15 MHz over a four day period and figure 35 shows the clear channels between 22 and 23 MHz. The solid lines represent clear channels with bandwidths greater than 12 kHz. In general it is not difficult to find adequate clear channels above 16 MHz. At lower frequencies there is some difficulty in that while there are some channels which remain clear for long periods of time (eg several hours) there are others which only appear during one surveillance run. The data in figures 34 and 35 were obtained with measurements of clear channels spaced at approximately 30 min intervals. Analysis of a number of examples similar to figure 34 suggests that a higher update rate of the surveillance data, combined with an algorithm which takes into account the the recent history of a given channel, is required to be able to define the probability that a given channel is likely to remain clear. This question cannot be fully explored because of the low repetition rate of the Stage A surveillance system.

(R) Another important question is are there any preferred bands for operation of the radar? That is, is any section of the spectrum more likely to remain clear than any other? Figures 36 to 39 show the mean power, in a 10 kHz bandwidth, relative to the background noise level as a percentage of all possible 10 kHz bandwidths within each service allocation band. The data are presented for representative times at which the given frequencies are likely to be required for radar operation. The most striking feature is the fact that the broadcast bands are virtually never suitable for operation since the signal level in any given 2 kHz channel is nearly always significantly greater than the background noise level.

6. NOISE LEVEL PREDICTIONS FOR STAGE B OPERATION

(U) Various aspects of the design of the Jindalee Stage B radar system require a knowledge of the minimum atmospheric noise levels which can be expected. Although it is possible to use the minimum noise levels recorded at each frequency it is more realistic to use the minimum noise levels at each frequency only for the times of day for which that frequency is likely to be used for radar operation. For example, it is not sensible to calculate radar signal-to-noise performance using the minimum noise level recorded over a 24 hour period at 6 MHz since this minimum will occur near midday whereas the radar will only use 6 MHz in the early hours of the morning when the noise level is 20 to 30 dB higher.

(U) Figure 40(a) shows the range of noise values measured over a one month period, the spread of values at a given frequency resulting from the diurnal variation. The solid line represents the internal noise level of the Stage A surveillance receiver and indicates that the data is subject to internal noise limitation below 11 MHz and above 18 MHz for at least some periods of the day. Figure 40(b) shows the range of noise values for those time periods for which a given frequency is likely to be used for radar operation within the range 1000 to 3000 km (data from reference 7). The principal effect is to eliminate some of the lowest noise values at low frequencies since these occur during times when the radar is unlikely to operate at these frequencies.

(U) In an attempt to overcome the internal noise limitation at high frequencies an inductor was connected between the whip and the cable to change the mismatch. In addition a 20 dB preamplifier was inserted in the system for measurements below 8 MHz and above 18 MHz. This preamplifier was not included for measurements between 8 and 18 MHz due to the presence of very strong broadcast band signals which caused overloading of the receiver, and because this frequency range was not in general internally noise limited. Figure 41 shows the losses in the modified system which must be added (as for figure 3) to convert the raw data into data for an equivalent loss-less antenna as per CCIR Report 322. Figure 42 shows the data for October 1978 in the same format as figure 40. The effect of the modified system can be seen at high frequencies where the noise levels are lower than in figure 40.

(U) The data for the eighteen months of Stage A operation were combined into a composite plot (by combining diagrams such as figure 40(b)) of the minimum noise level that can be expected at any frequency for the times of day when that frequency is likely to be used for radar operation with the ranges between 1000 and 3000 km. Figure 43 thus includes seasonal effects and shows the minimum noise that can be expected during Stage B radar operations.

7. CONCLUSIONS

(U) A summary of the main features of the HF environment at Alice Springs during 1977 and 1978 has been presented. The background atmospheric noise levels have a greater diurnal range than predicted by the standard CCIR model, due largely to the fact that the CCIR model consistently overestimates the noise levels during the day. The seasonal variation in atmospheric noise levels was significantly smaller than predicted by the CCIR model. Examples have been presented of the distribution of signal strengths over the HF spectrum, as well as of the dynamic range required for a receiver to be capable of simultaneously measuring the background noise level and the largest

signals which may be present in the various regions of the HF spectrum.

(U) Clear channels of 10 kHz bandwidth can almost always be located at frequencies above 12 MHz. The greatest difficulty in locating adequate clear channels occurs in the early morning hours when propagation conditions require the use of frequencies in the range 6 to 10 MHz. At these times there is severe congestion in these bands and it may be necessary to resort to clear channels of 4 kHz bandwidth. Although in general it is not difficult to locate a nominally clear channel based on one surveillance run of the Stage A system, a greater update rate combined with an algorithm which takes into account the past history of a given channel is required if it is desired to provide a measure of the likelihood that a given clear channel will remain clear.

REFERENCES

No.	Author	Title
1	Mettyear, W.	"Summary Report on Stage A of Project Jindalee". ERL-B124-TR
2	Earl, G.F. and Garrett, R.E.	"Project Jindalee: Frequency Management System for Stage A". (In preparation)
3	Earl, G.F., Ward, B.D. and Garrett, R.E.	"Project Jindalee, An Evaluation of the Stage A Surveillance Receiver". ERL-B130-TR
4	CCIR 1964	World Distribution and Characteristics of Atmospheric Radio Noise, Report 322, ITU, Geneva
5	Headrick, J.M. et al	Virtual Path Tracing for HF Radar including an Ionospheric Model, NRL Memorandum Report 2226
6	Ward, B.D.	"Project Jindalee: Receiver Out-of-Band Intermodulation Distortion in Stages A and B". ERL-B121-TR
7	Golley, M.G. and Blesing, R.G.	"Project Jindalee - System Performance Predictions for Stage B". WRE-TM-B70
8	Lucas, D.L. and Hooper, J.D.	A numerical representation of CCIR Report 322, "High Frequency Atmospheric Radio Noise Data". NBS Tech Note 318, 1965
9	Earl, G.F.	"Project Jindalee - Noise Analysis of the Stage A Receiving Antenna". WRE-TM-B84

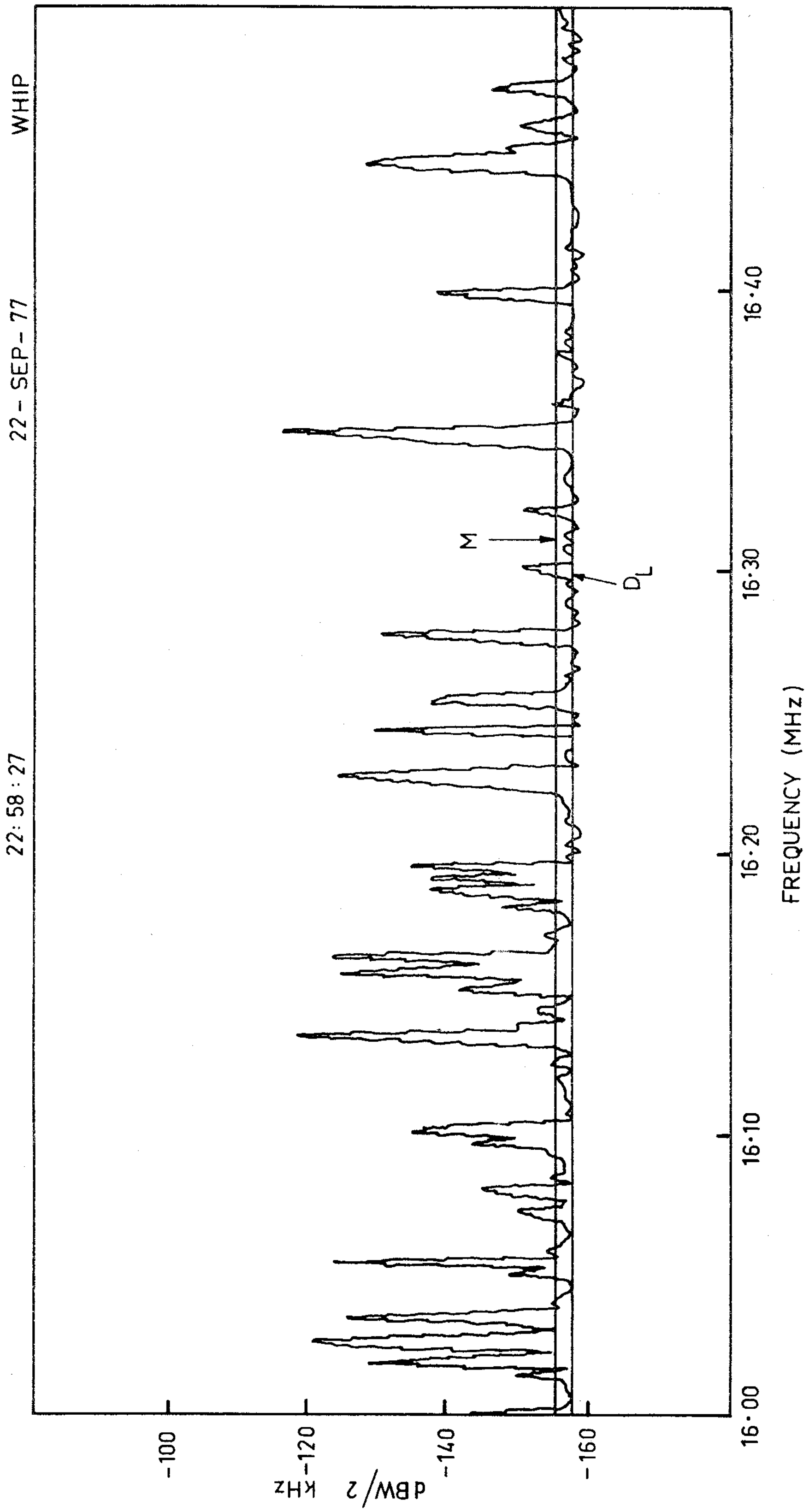

FIGURE 1 A PORTION OF THE HF SPECTRUM WITH A SMALL NUMBER OF DISCRETE RF SOURCES

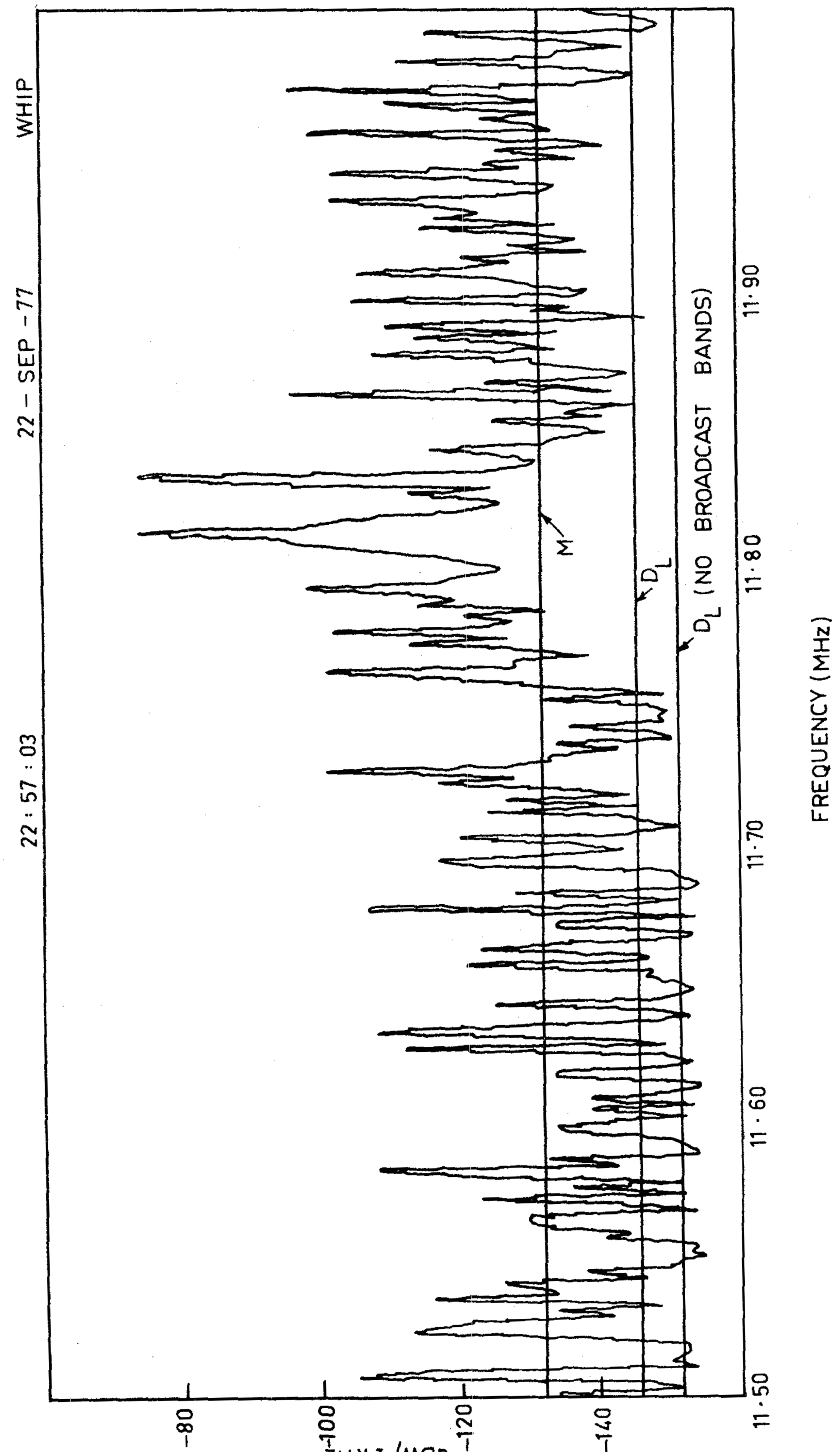

FIGURE 2 A PORTION OF THE HF SPECTRUM WITH A LARGE NUMBER OF BROADCAST BAND SIGNALS

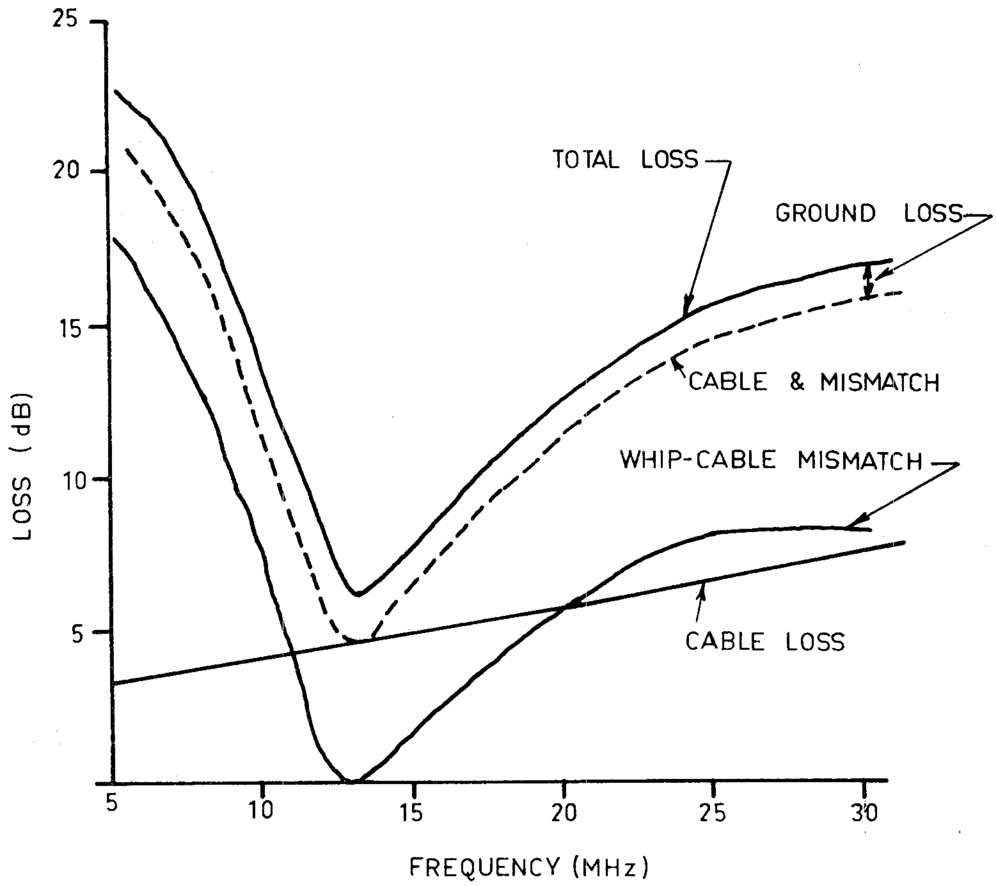

FIGURE 3 CORRECTION FACTORS APPLIED TO WHIP DATA

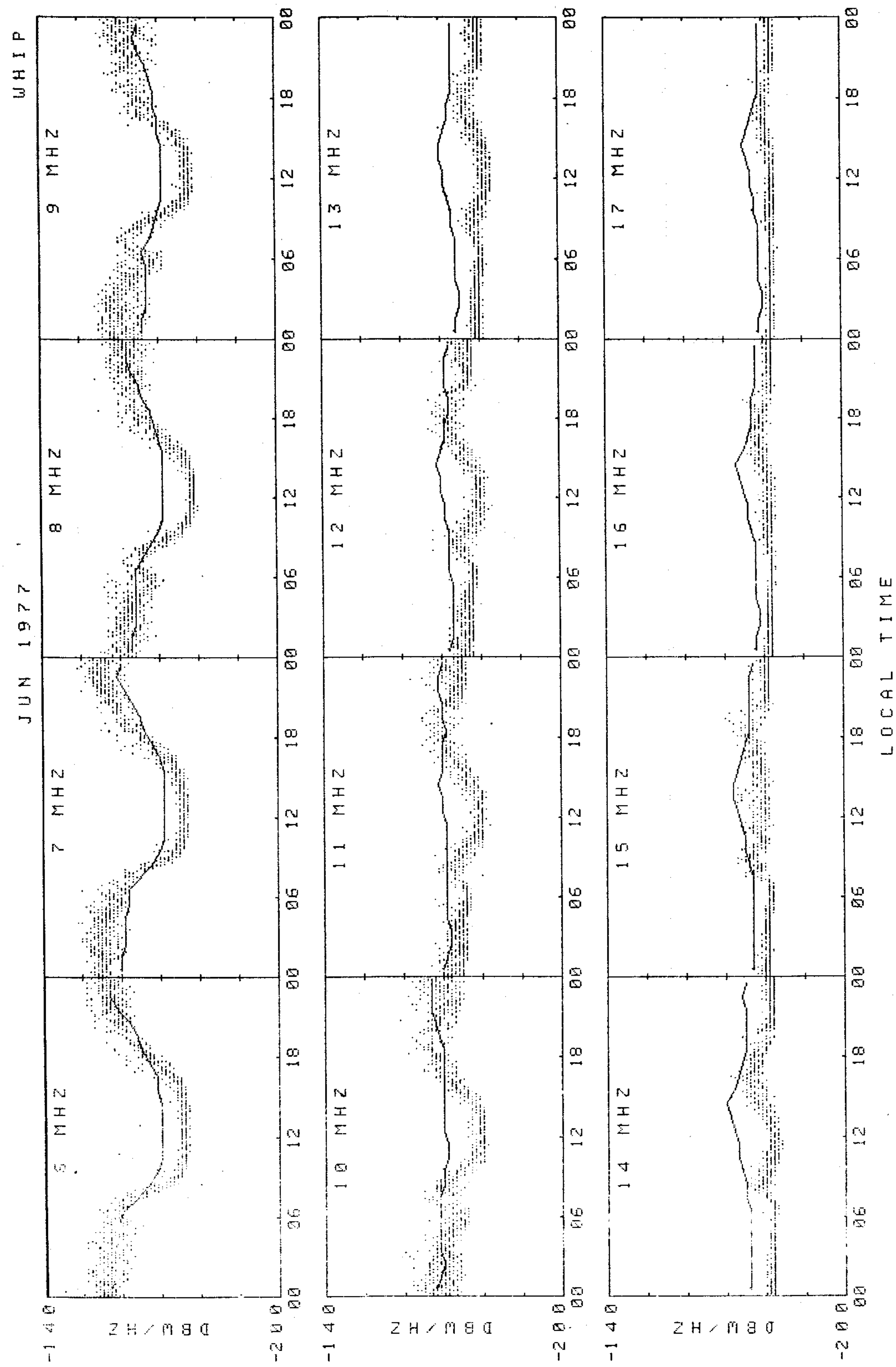

FIGURE 4 DIURNAL VARIATION OF ATMOSPHERIC NOISE ON A WHIP ANTENNA - JUNE 1977

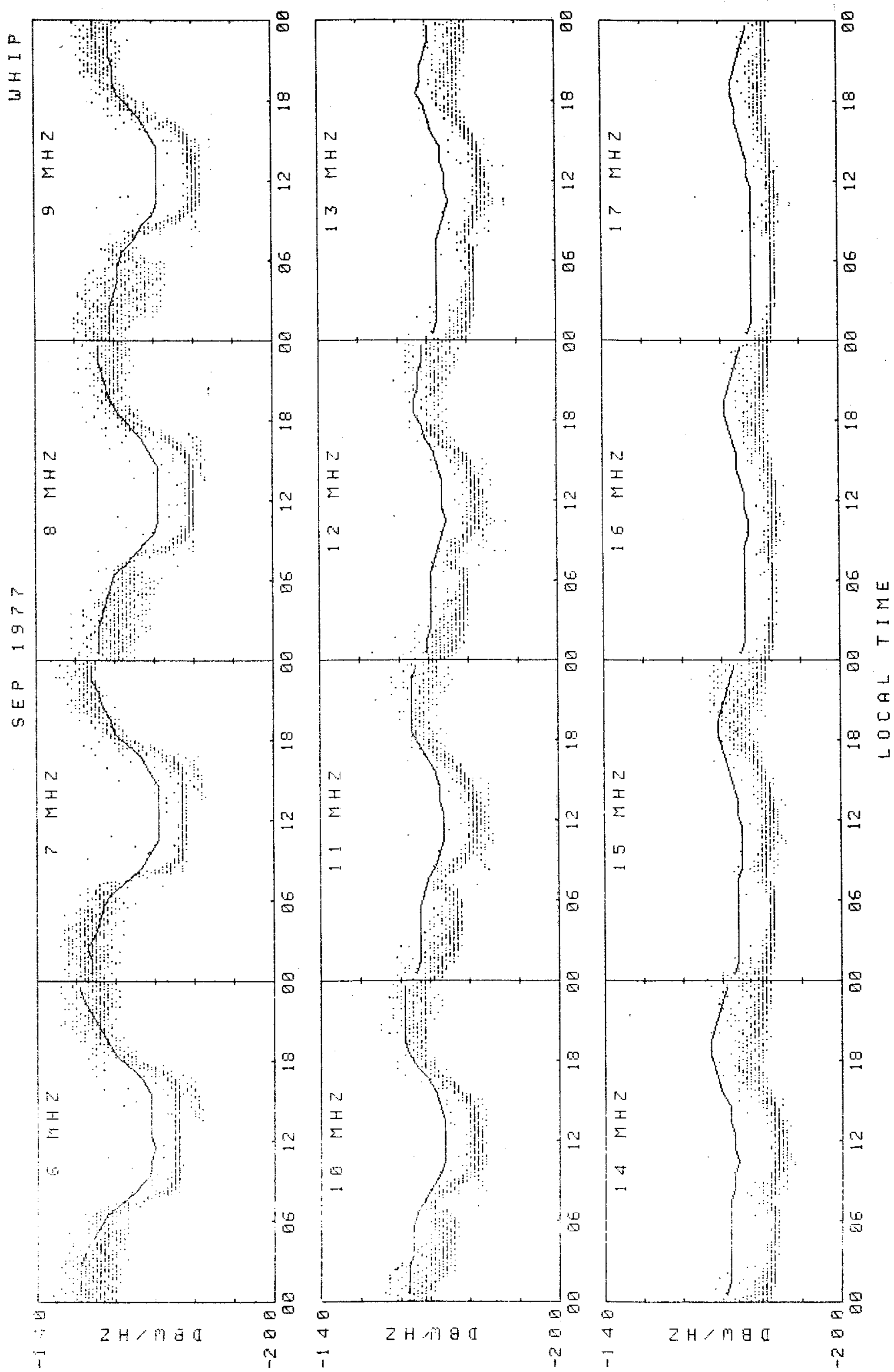

FIGURE 5 DIURNAL VARIATION OF ATMOSPHERIC NOISE ON A WHIP ANTENNA - SEPTEMBER 1977

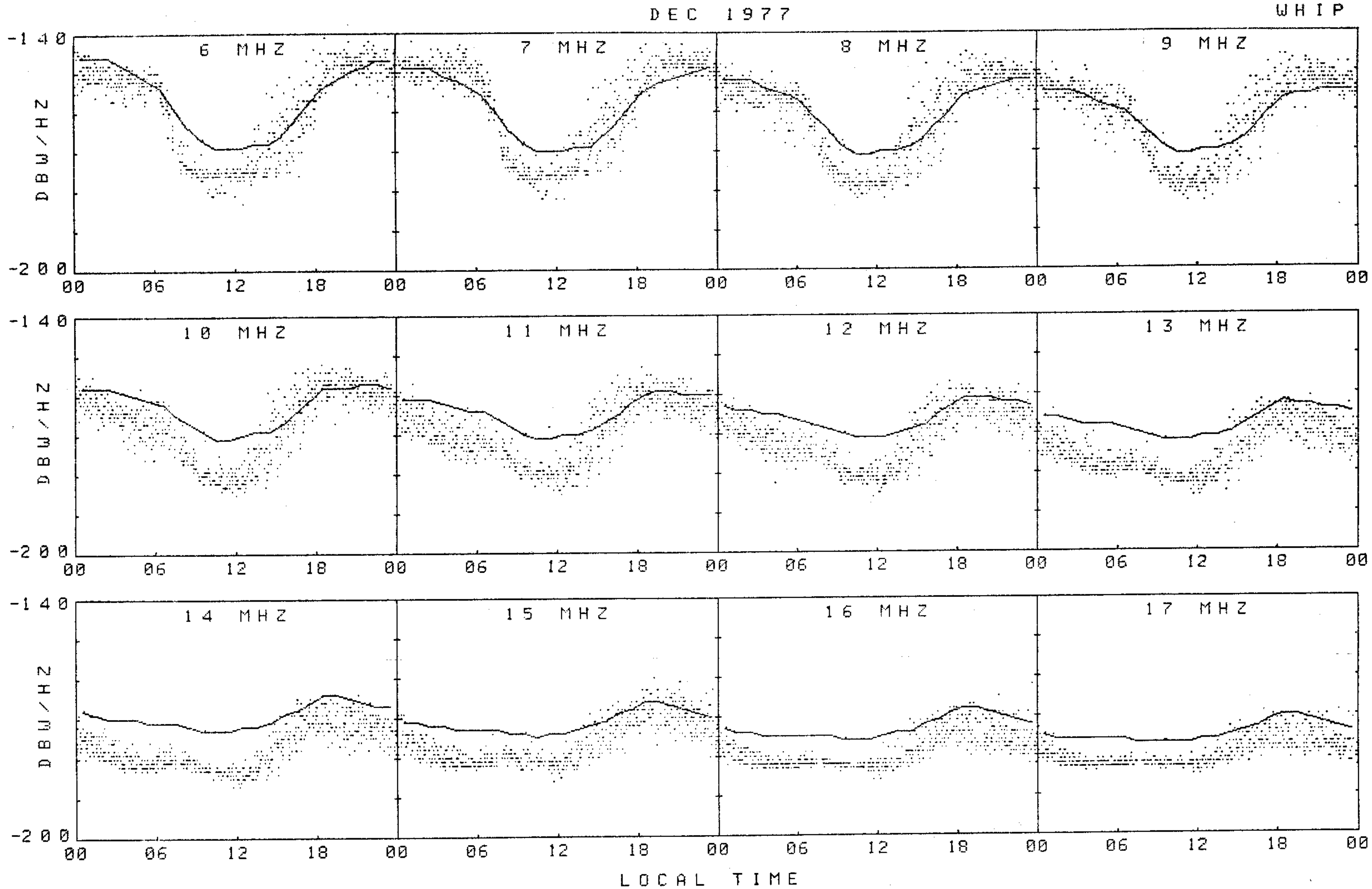

FIGURE 6 DIURNAL VARIATION OF ATMOSPHERIC NOISE ON A WHIP ANTENNA - DECEMBER 1977

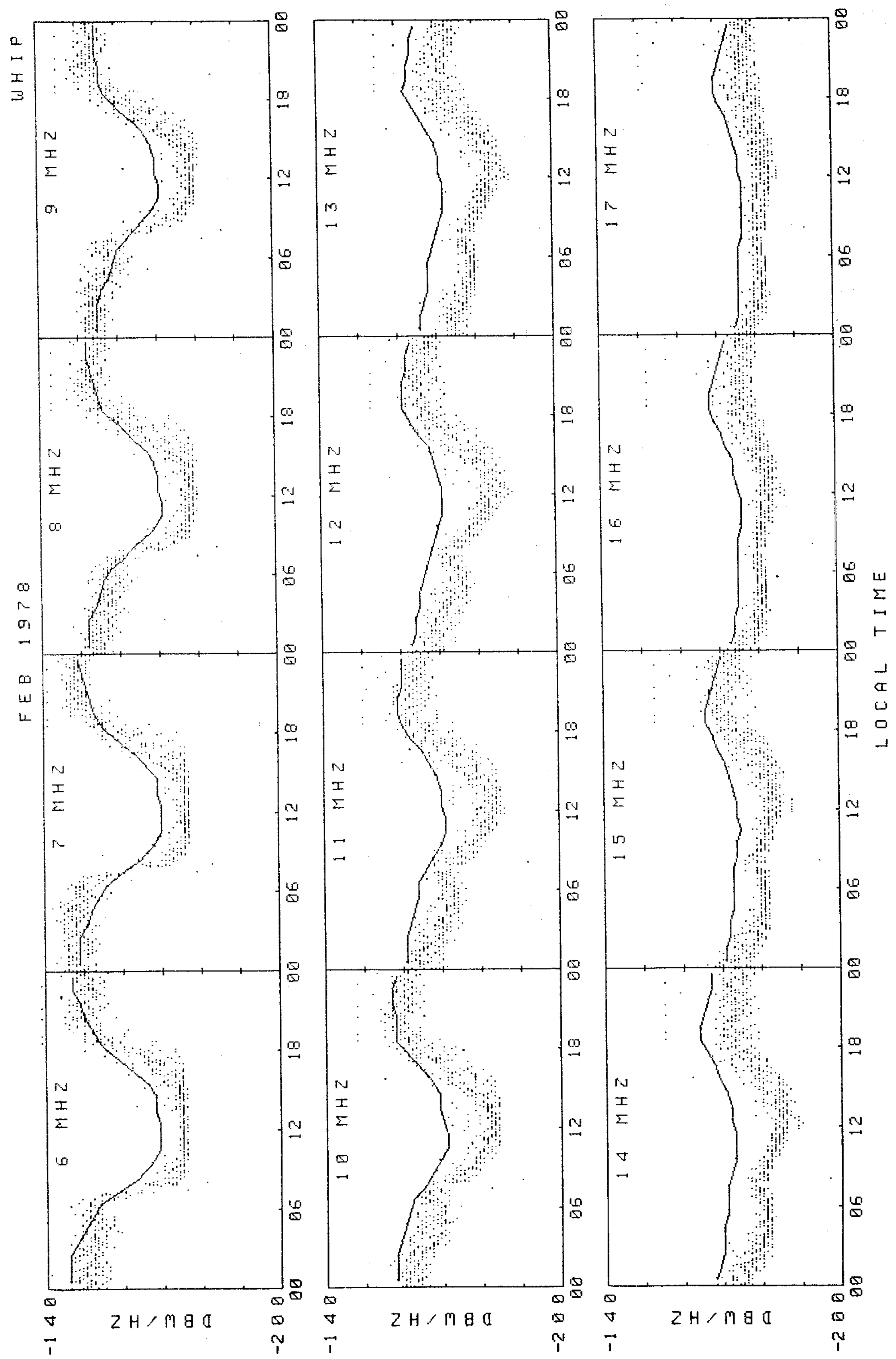

FIGURE 7 DIURNAL VARIATION OF ATMOSPHERIC NOISE ON A WHIP ANTENNA - FEBRUARY 1978

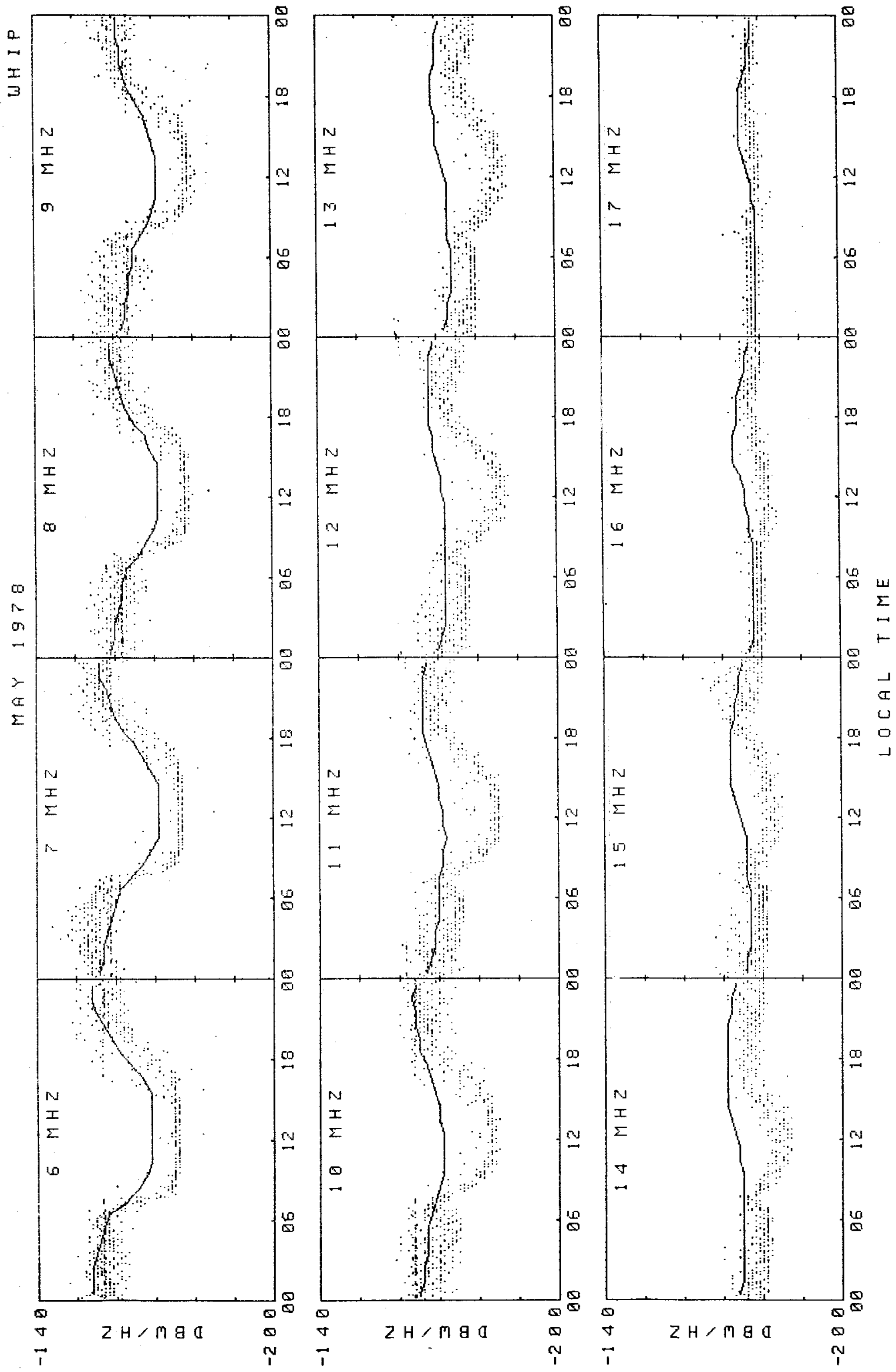

FIGURE 8 DIURNAL VARIATION OF ATMOSPHERIC NOISE ON A WHIP ANTENNA - MAY 1978

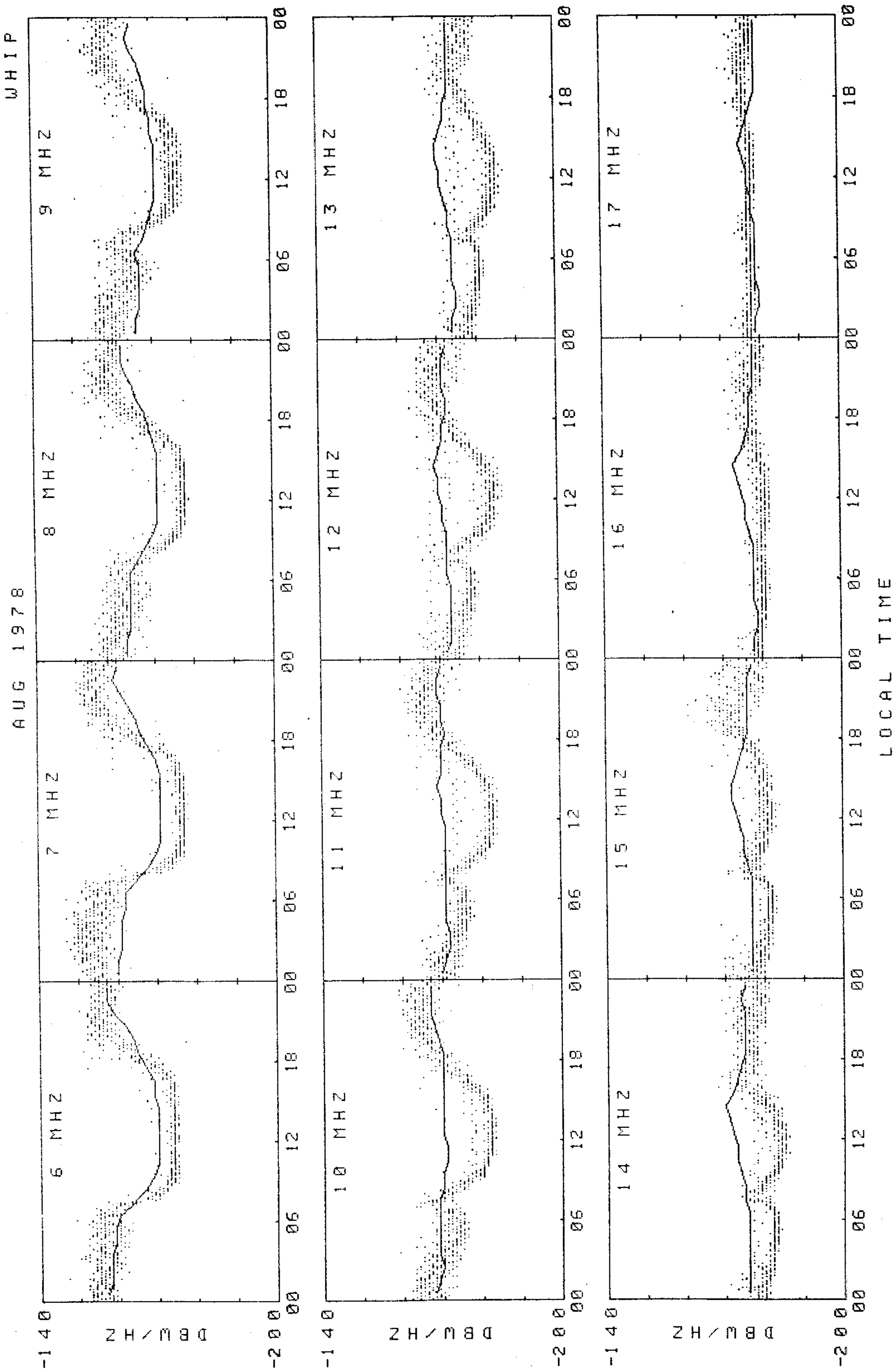

FIGURE 9 DIURNAL VARIATION OF ATMOSPHERE NOISE ON A WHIP ANTENNA - AUGUST 1978

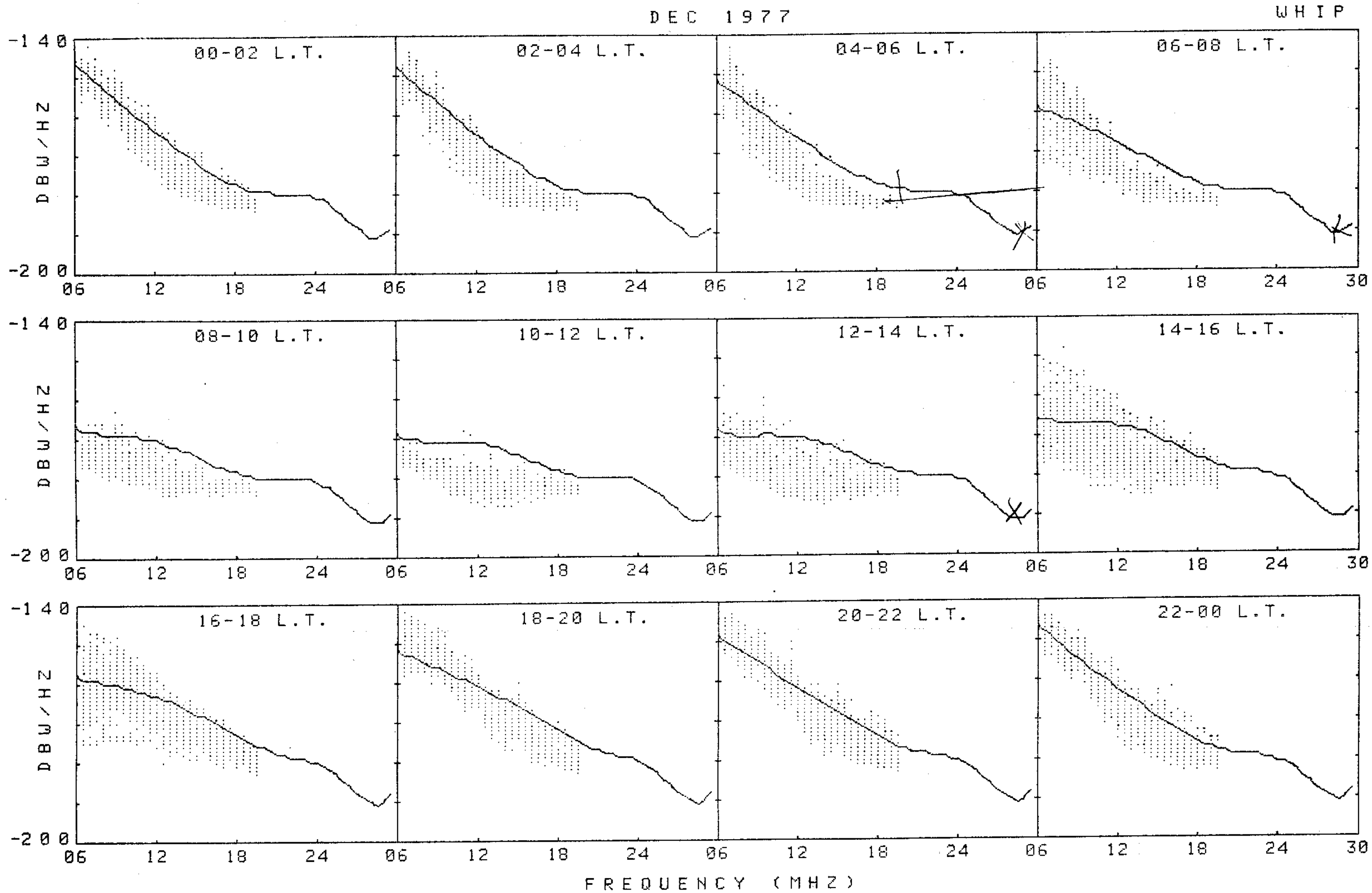

FIGURE 10 FREQUENCY VARIATION OF ATMOSPHERIC NOISE - DECEMBER 1977

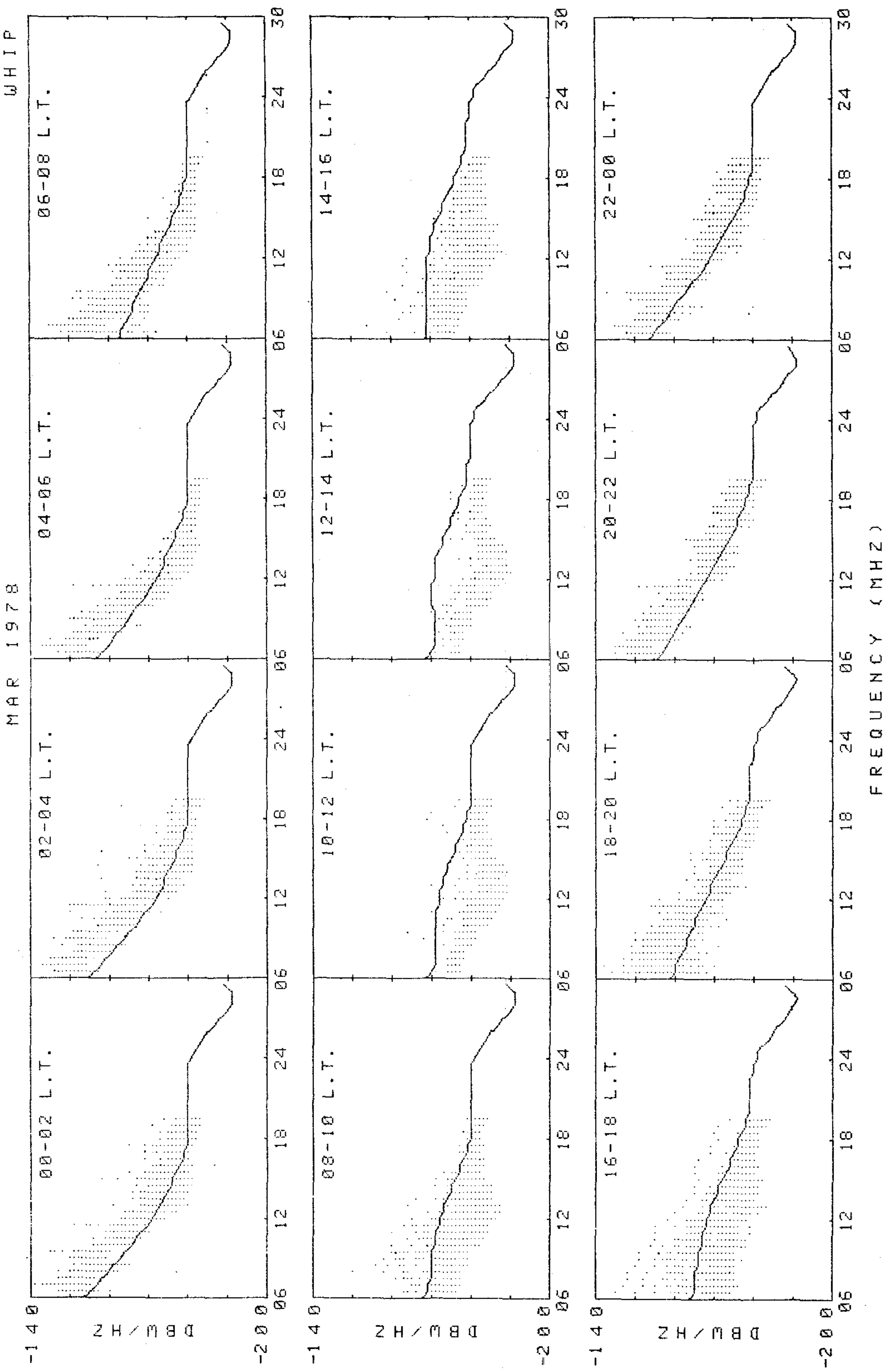

FIGURE 11 FREQUENCY VARIATION OF ATMOSPHERIC NOISE - MARCH 1978

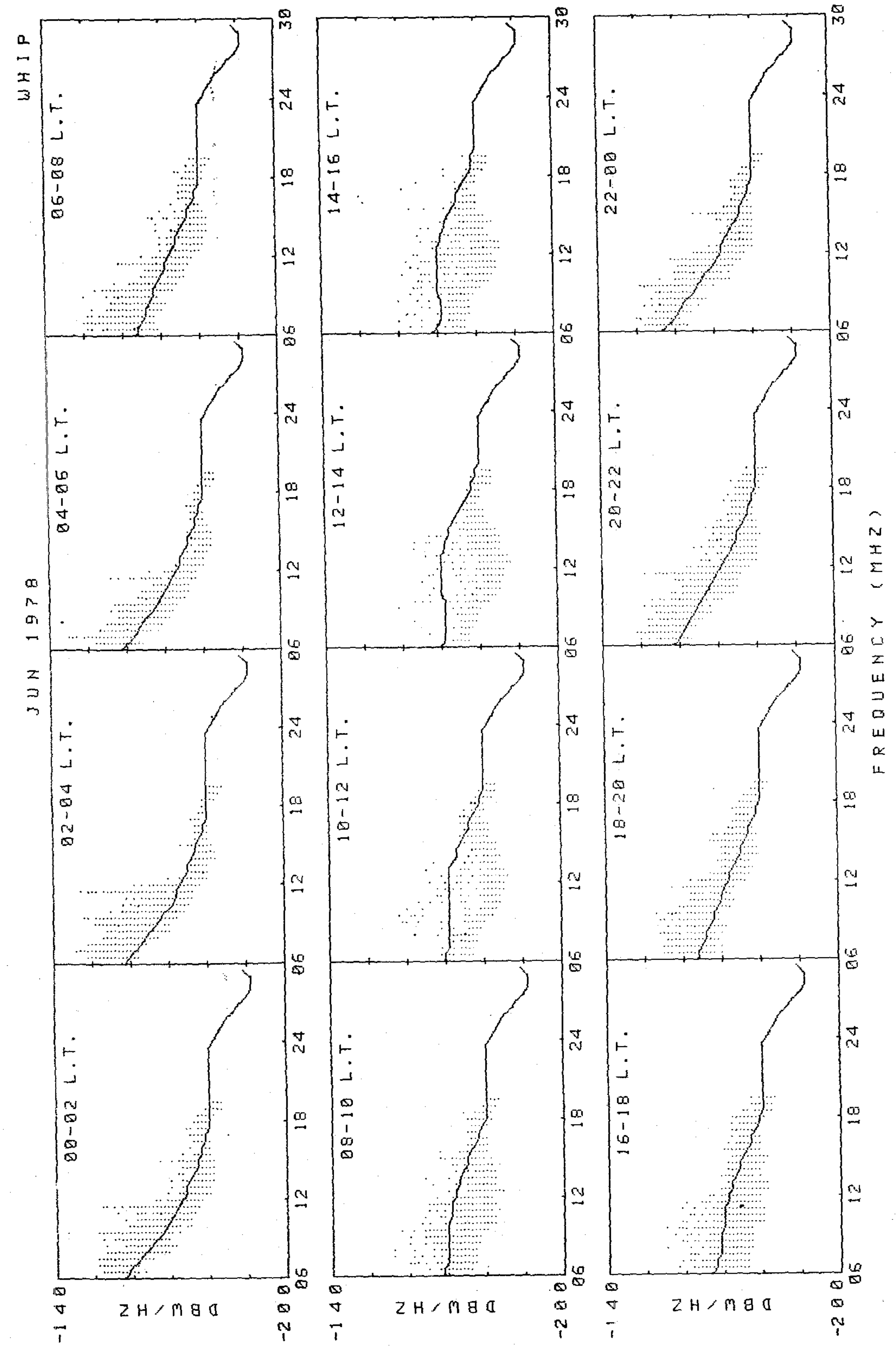

FIGURE 12 FREQUENCY VARIATION OF ATMOSPHERIC NOISE - JUNE 1978

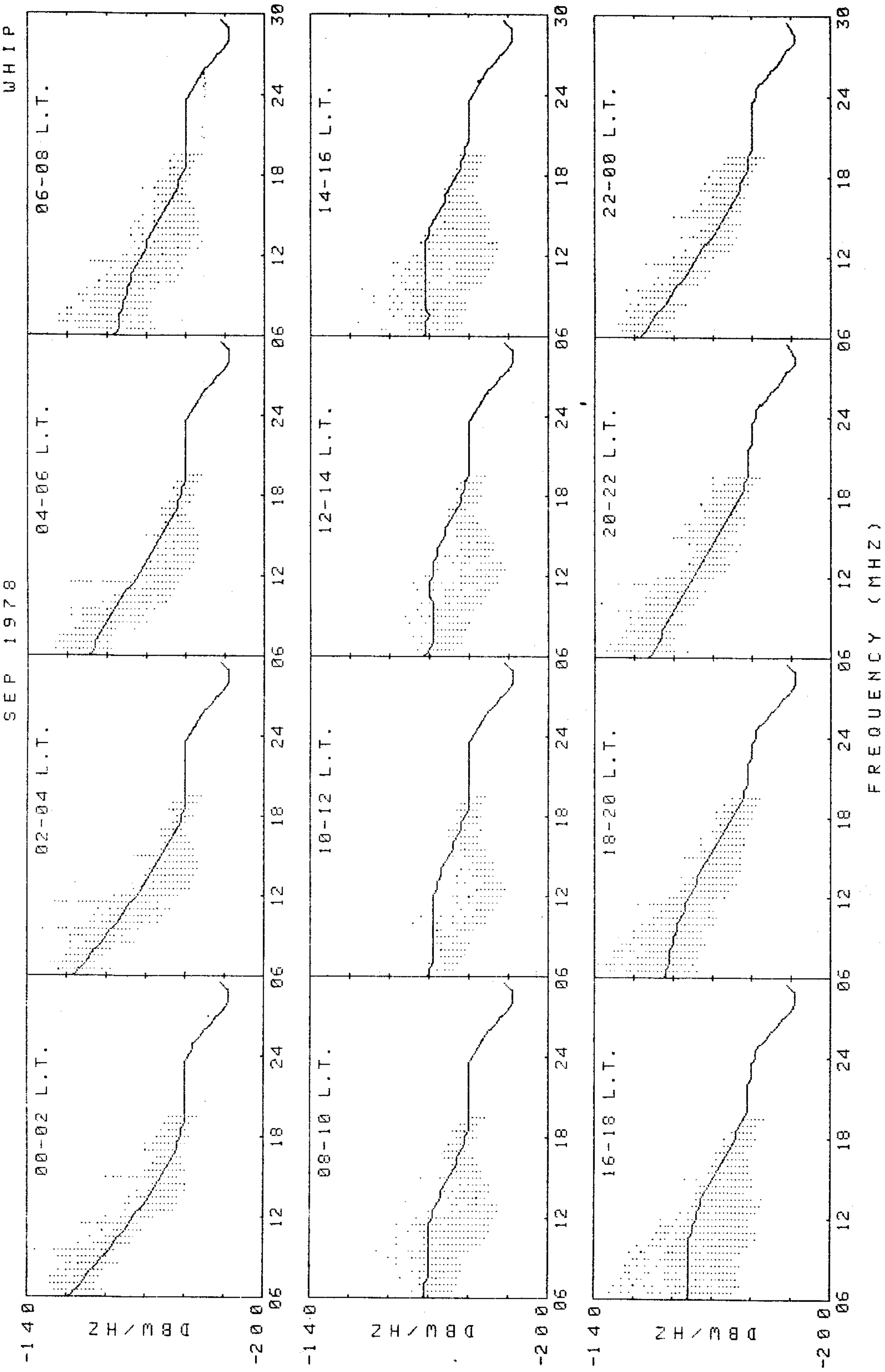

FIGURE 13 FREQUENCY VARIATION OF ATMOSPHERIC NOISE - SEPTEMBER 1978

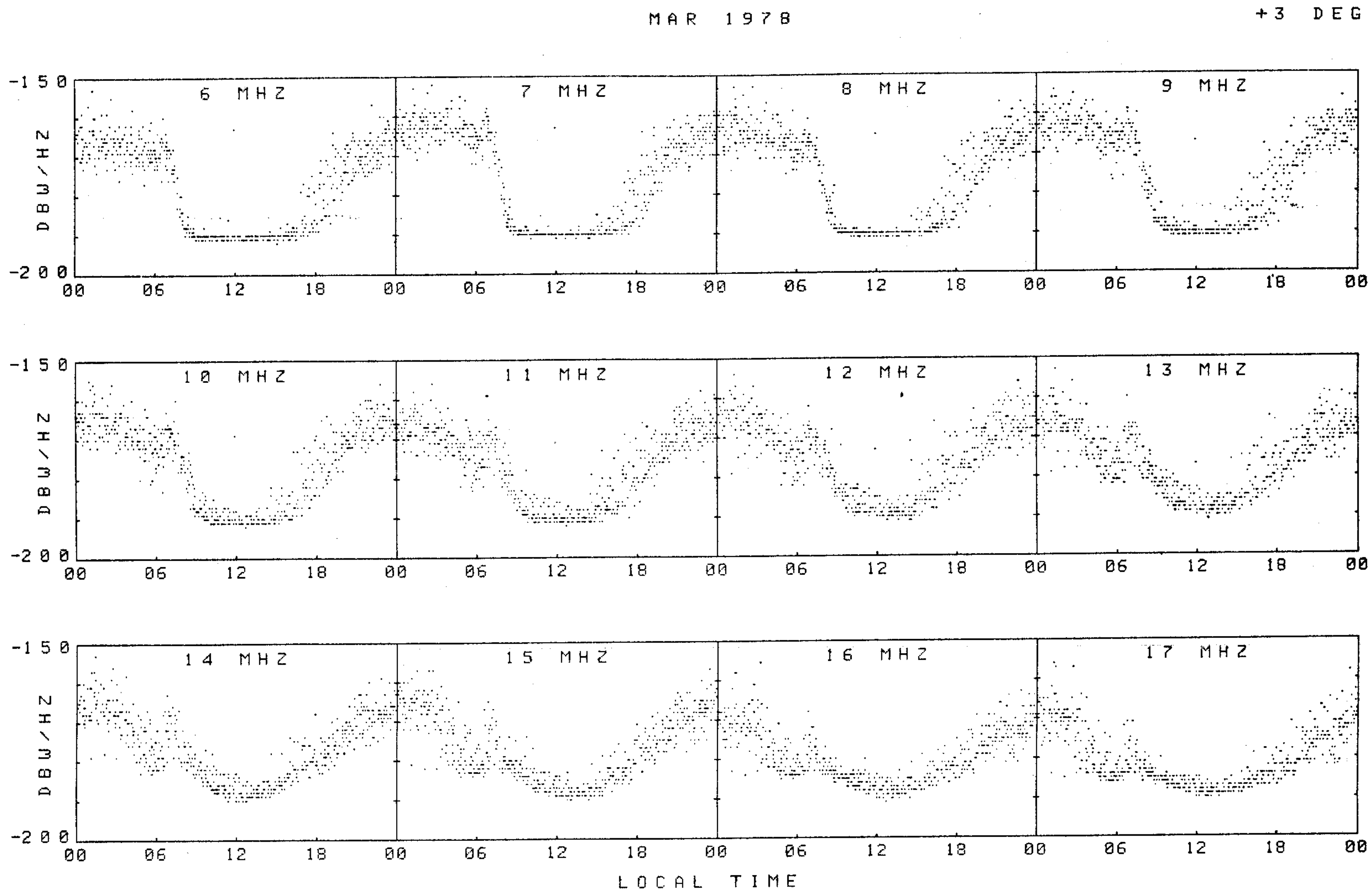

FIGURE 14 DIURNAL VARIATION OF ATMOSPHERIC NOISE ON A DIRECTIONAL ANTENNA - MARCH 1978

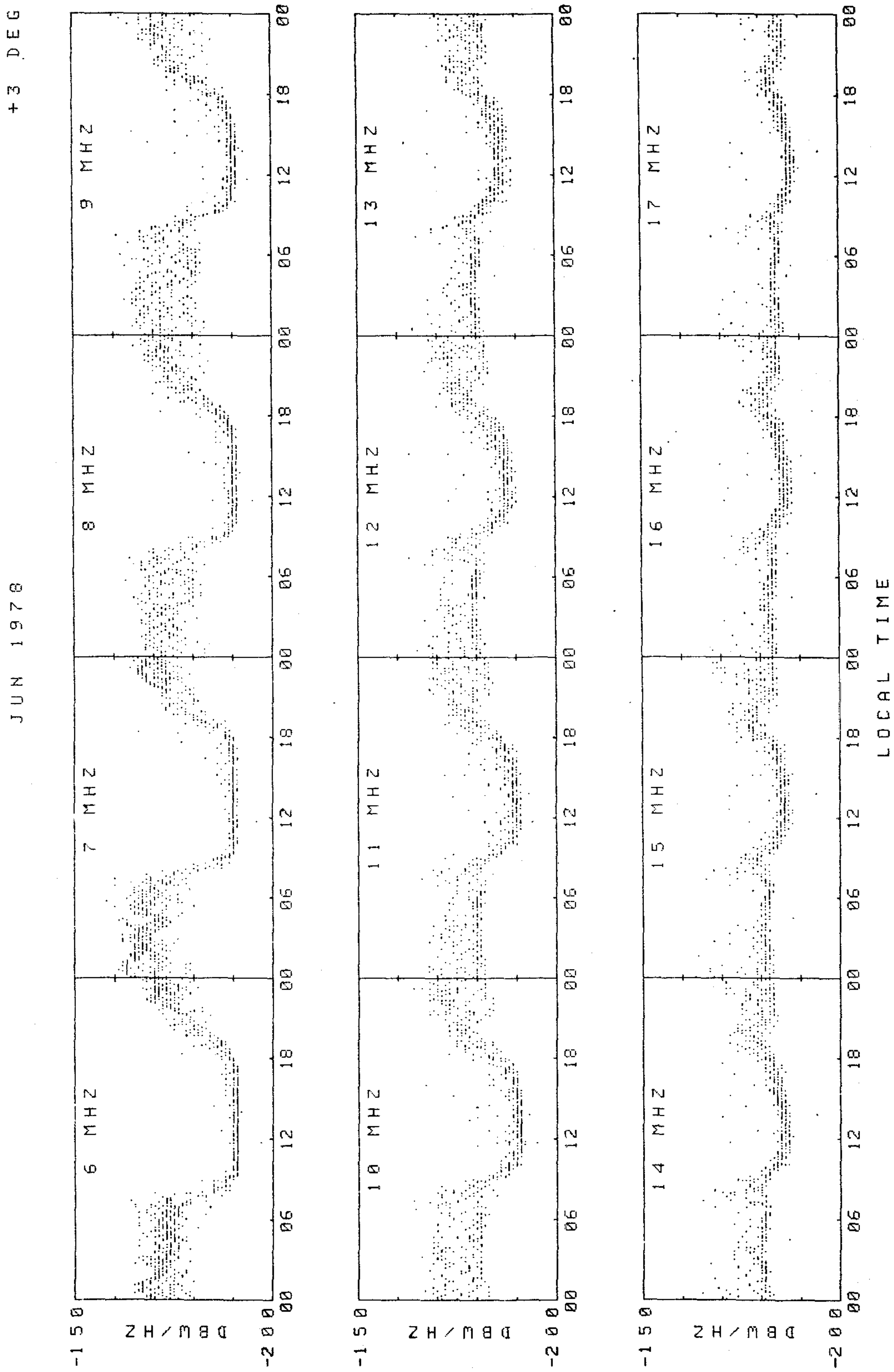

FIGURE 15 DIURNAL VARIATION OF ATMOSPHERIC NOISE ON A DIRECTIONAL ANTENNA - JUNE 1978

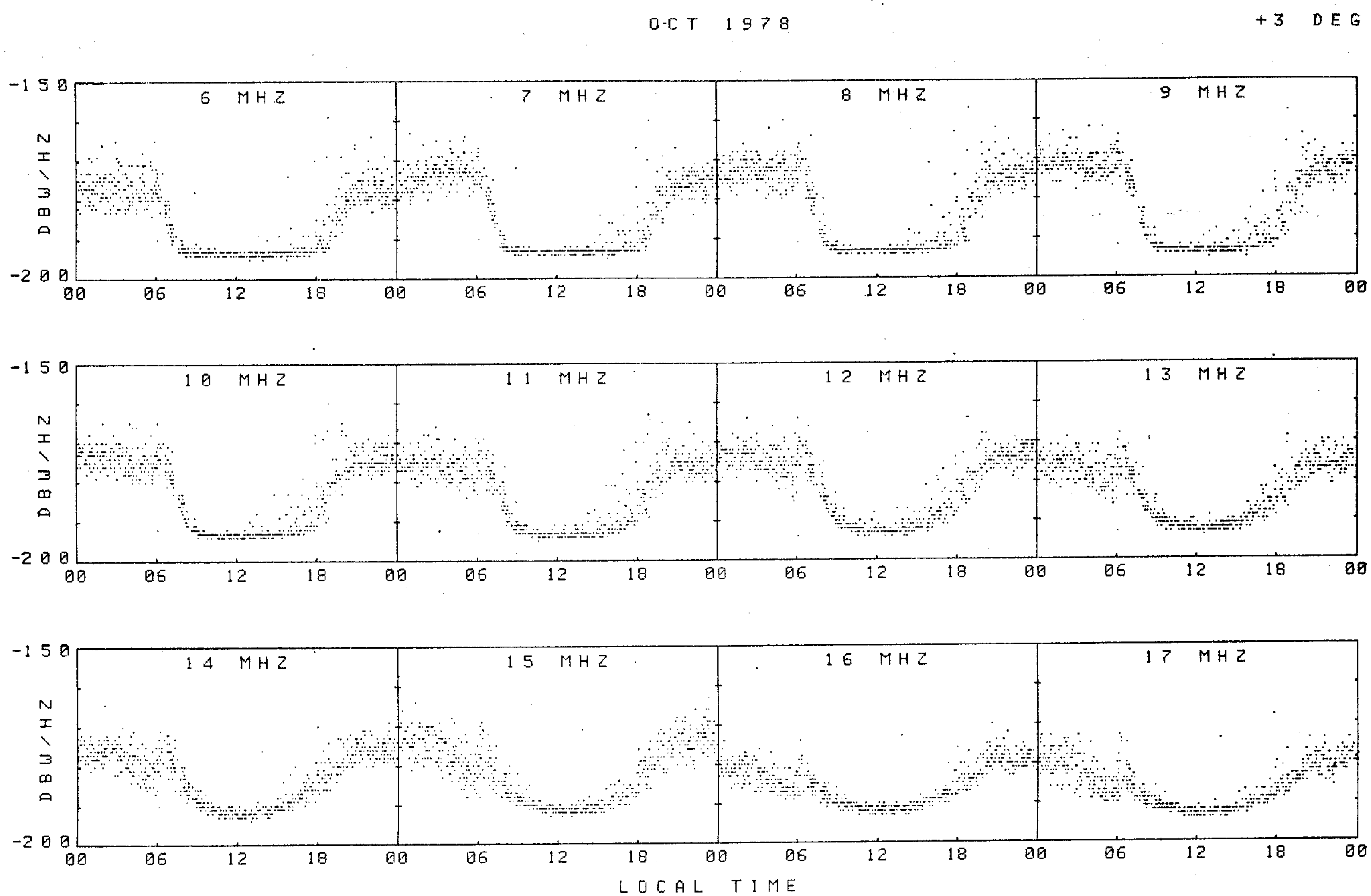

FIGURE 16 DIURNAL VARIATION OF ATMOSPHERIC NOISE ON A DIRECTIONAL ANTENNA - SEPTEMBER 1978

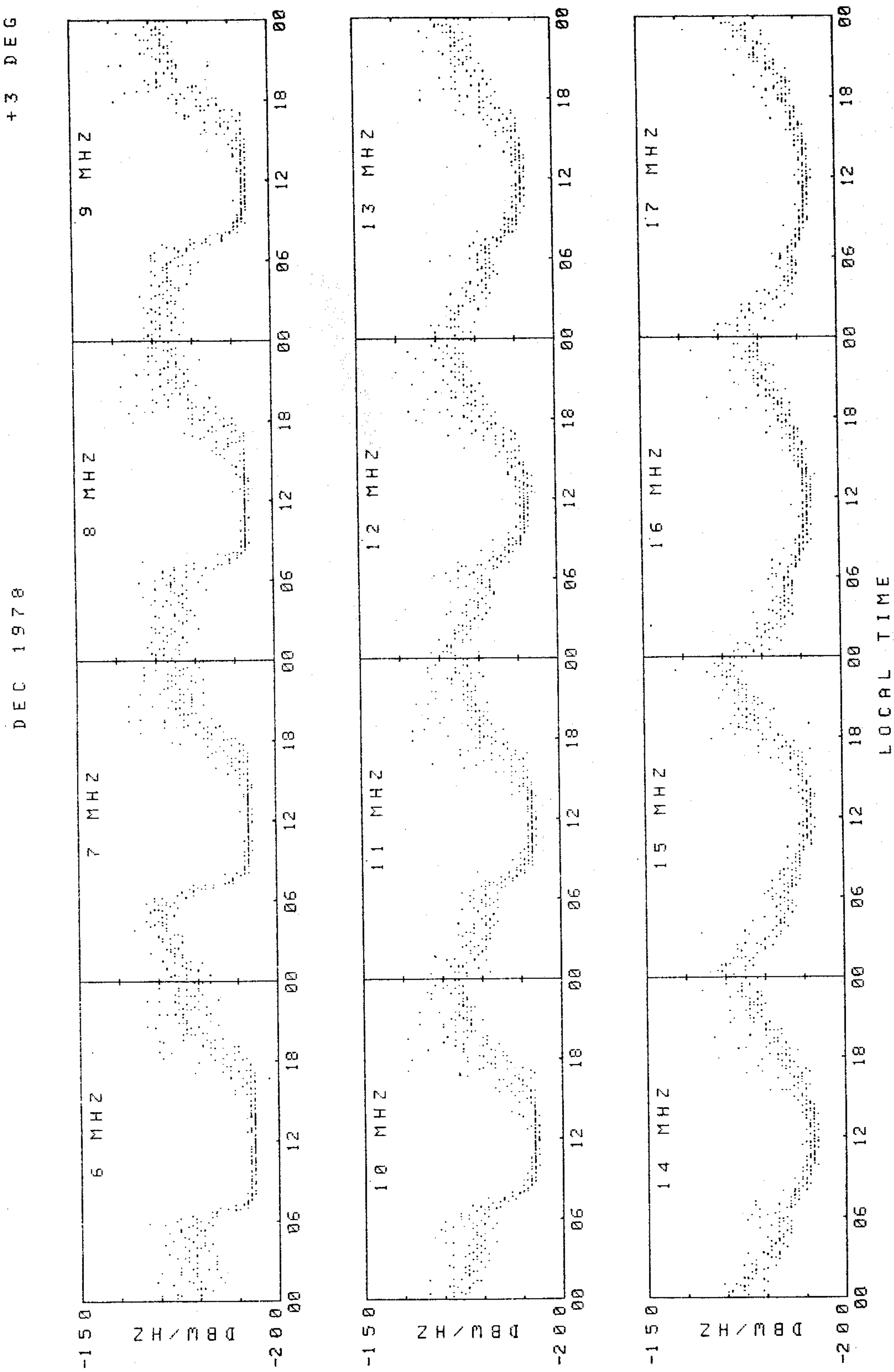

FIGURE 17 DIURNAL VARIATION OF ATMOSPHERIC NOISE ON A DIRECTIONAL ANTENNA - DECEMBER 1978

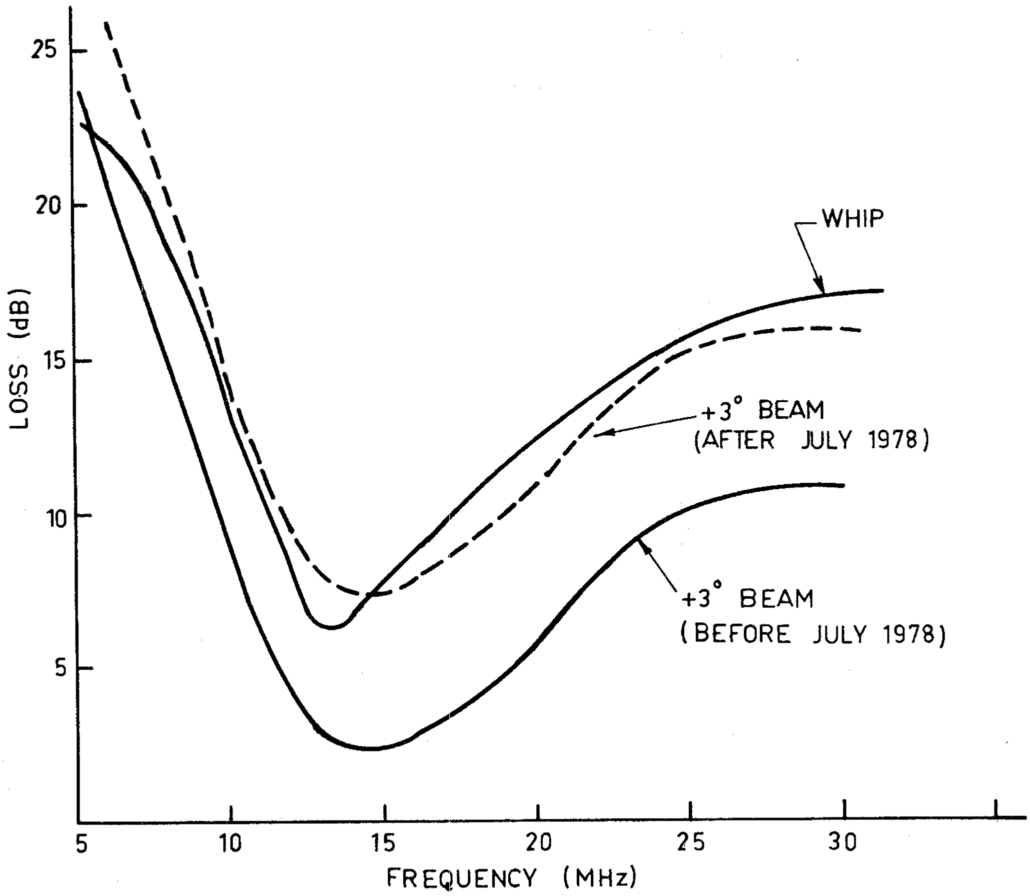

FIGURE 18 LOSSES IN THE STAGE A RADAR RECEIVING ANTENNA

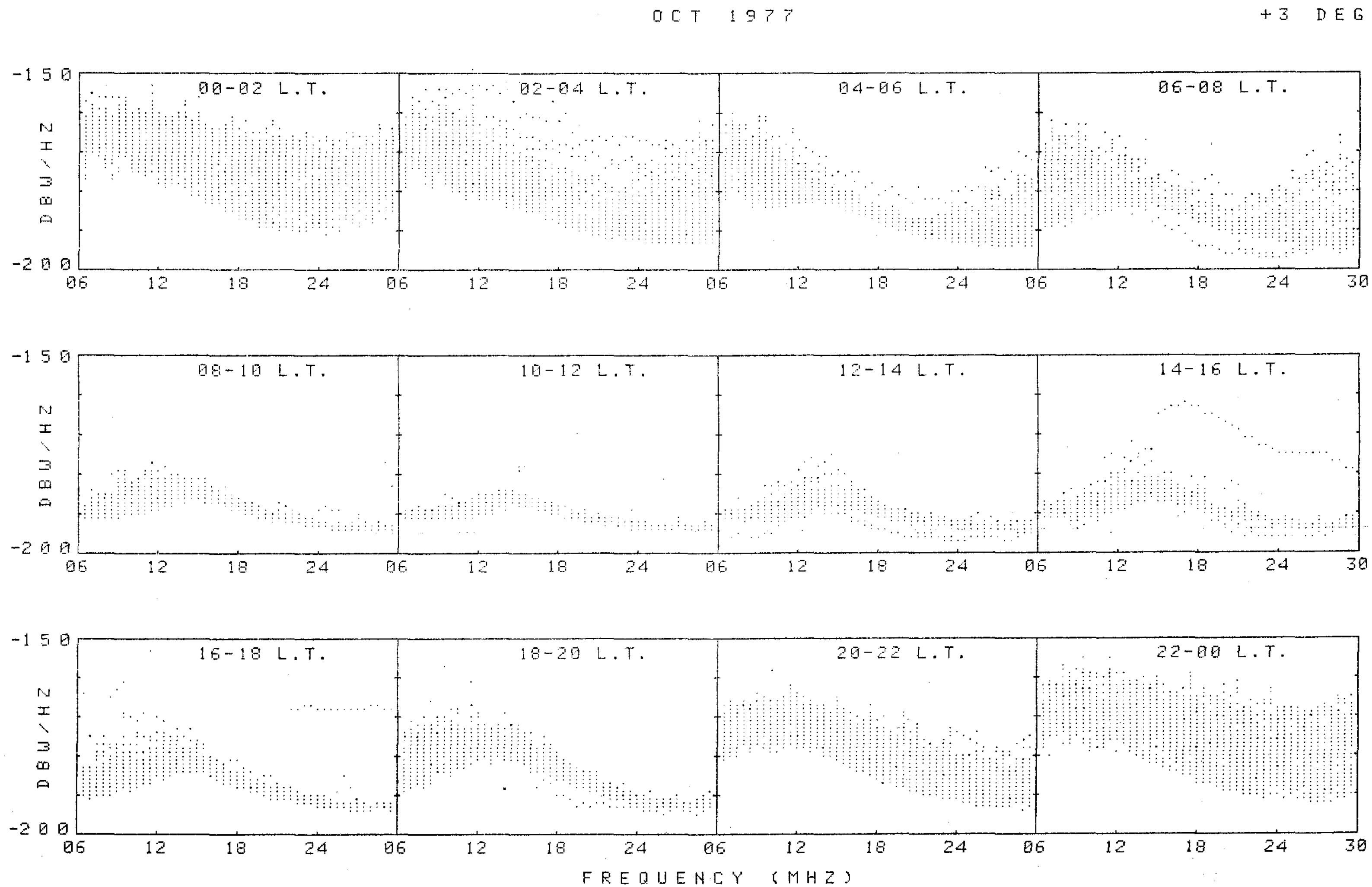

FIGURE 19 FREQUENCY VARIATION OF ATMOSPHERIC NOISE ON A DIRECTIONAL ANTENNA - OCTOBER 1977

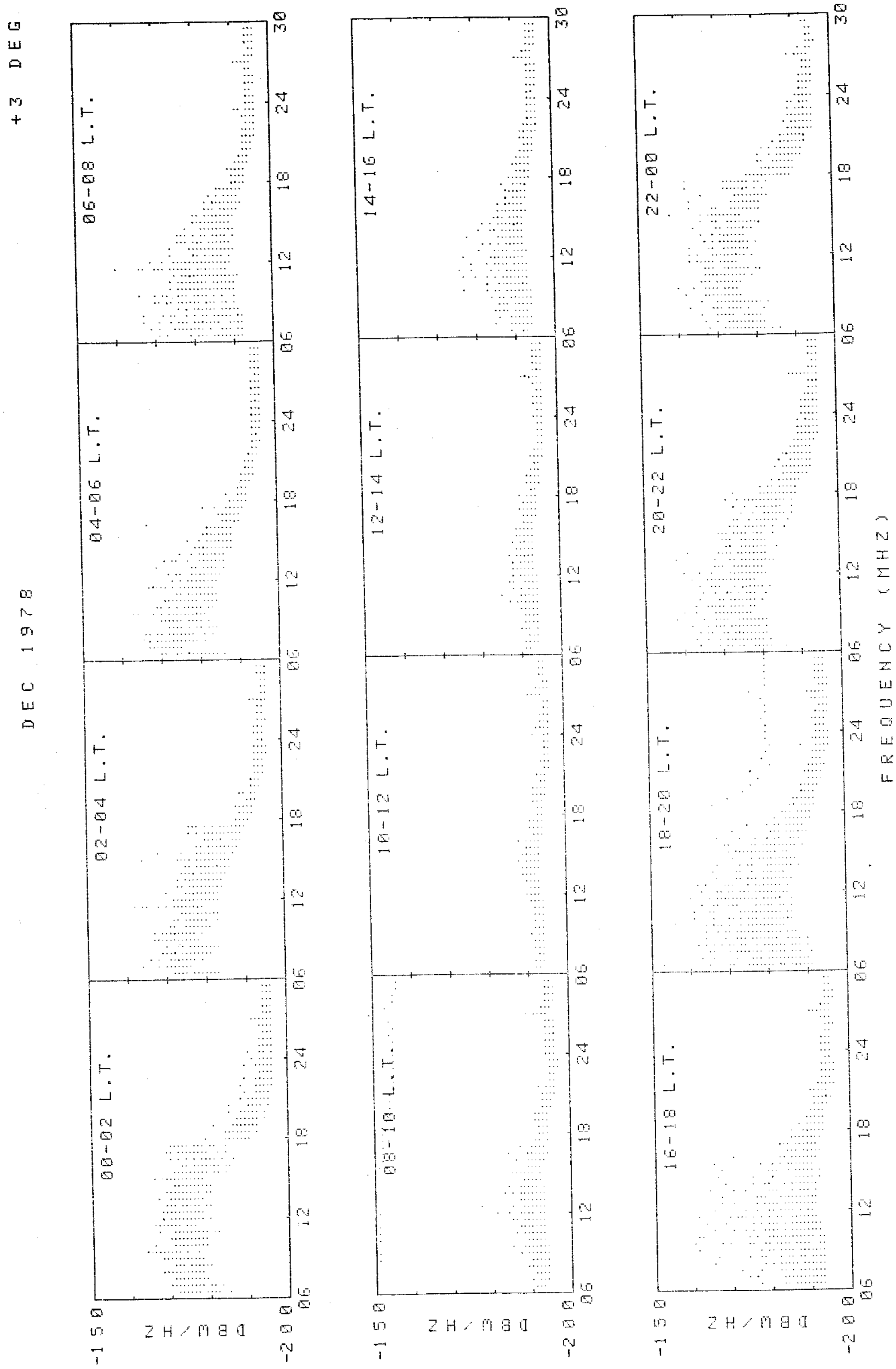

FIGURE 20 FREQUENCY VARIATION OF ATMOSPHERIC NOISE ON A DIRECTIONAL ANTENNA - DECEMBER 1978

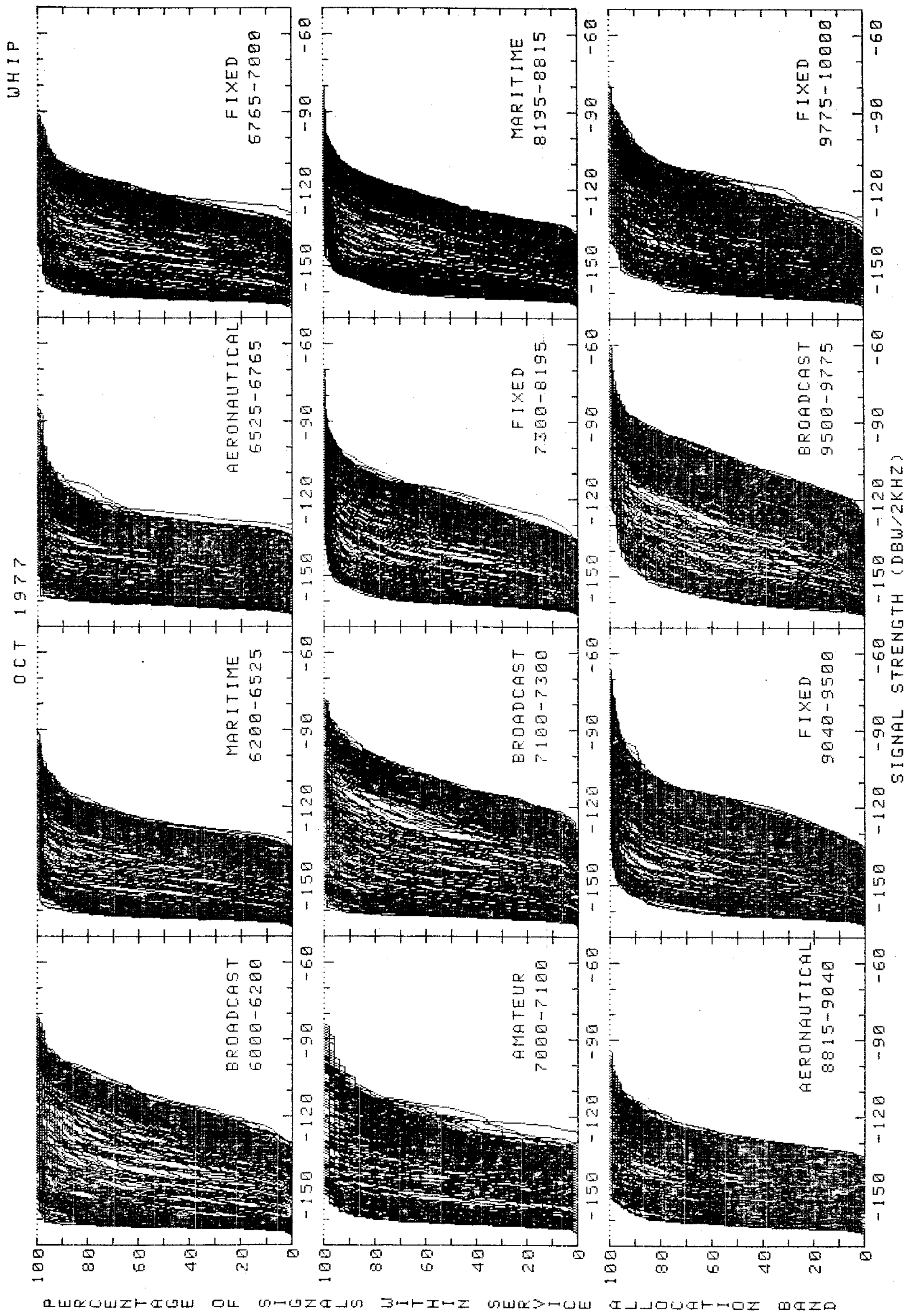

FIGURE 21 SIGNAL DISTRIBUTIONS: 6-10 MHz OCTOBER 1977

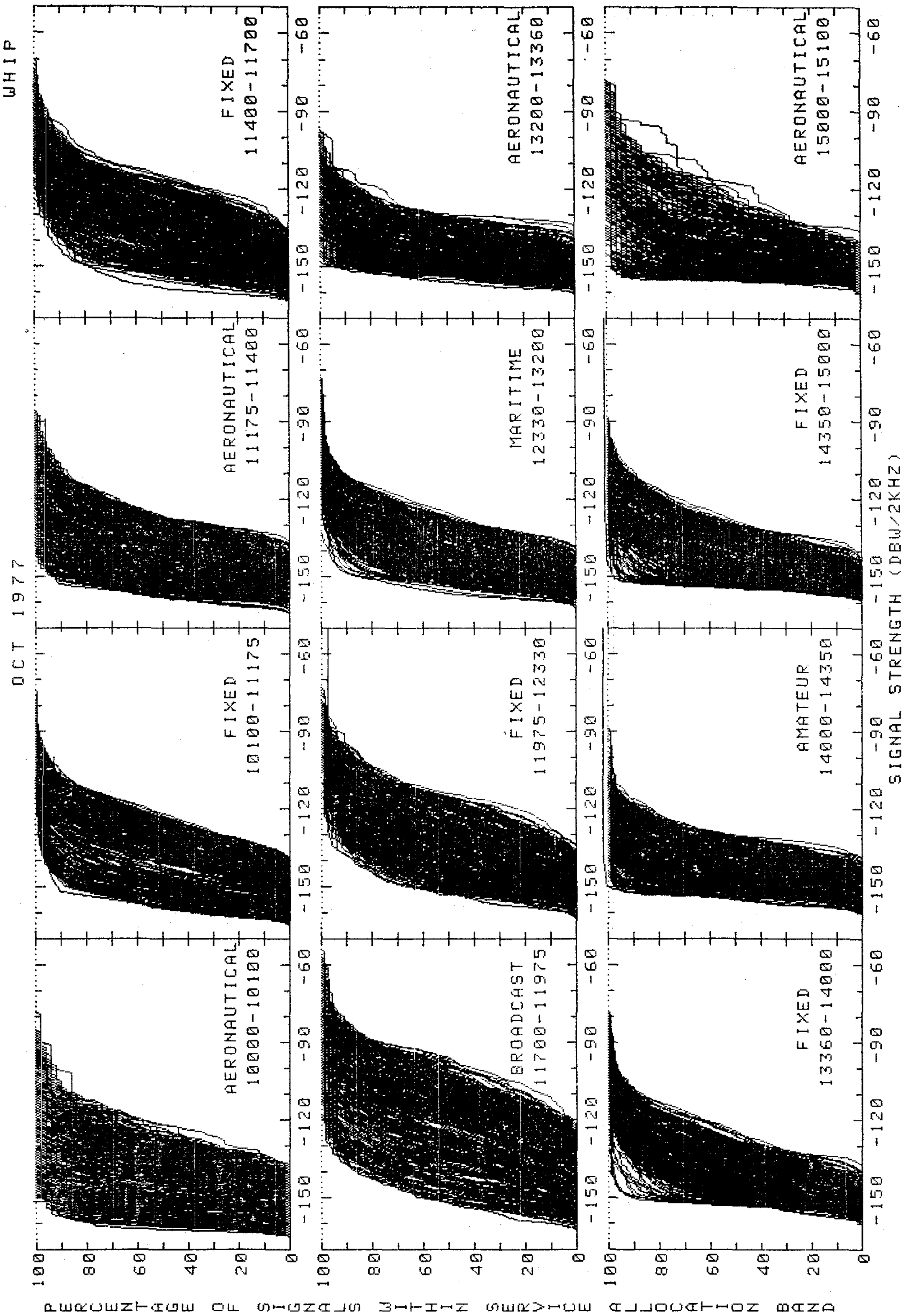

FIGURE 22 SIGNAL DISTRIBUTIONS: 10-15 MHz OCTOBER 1977

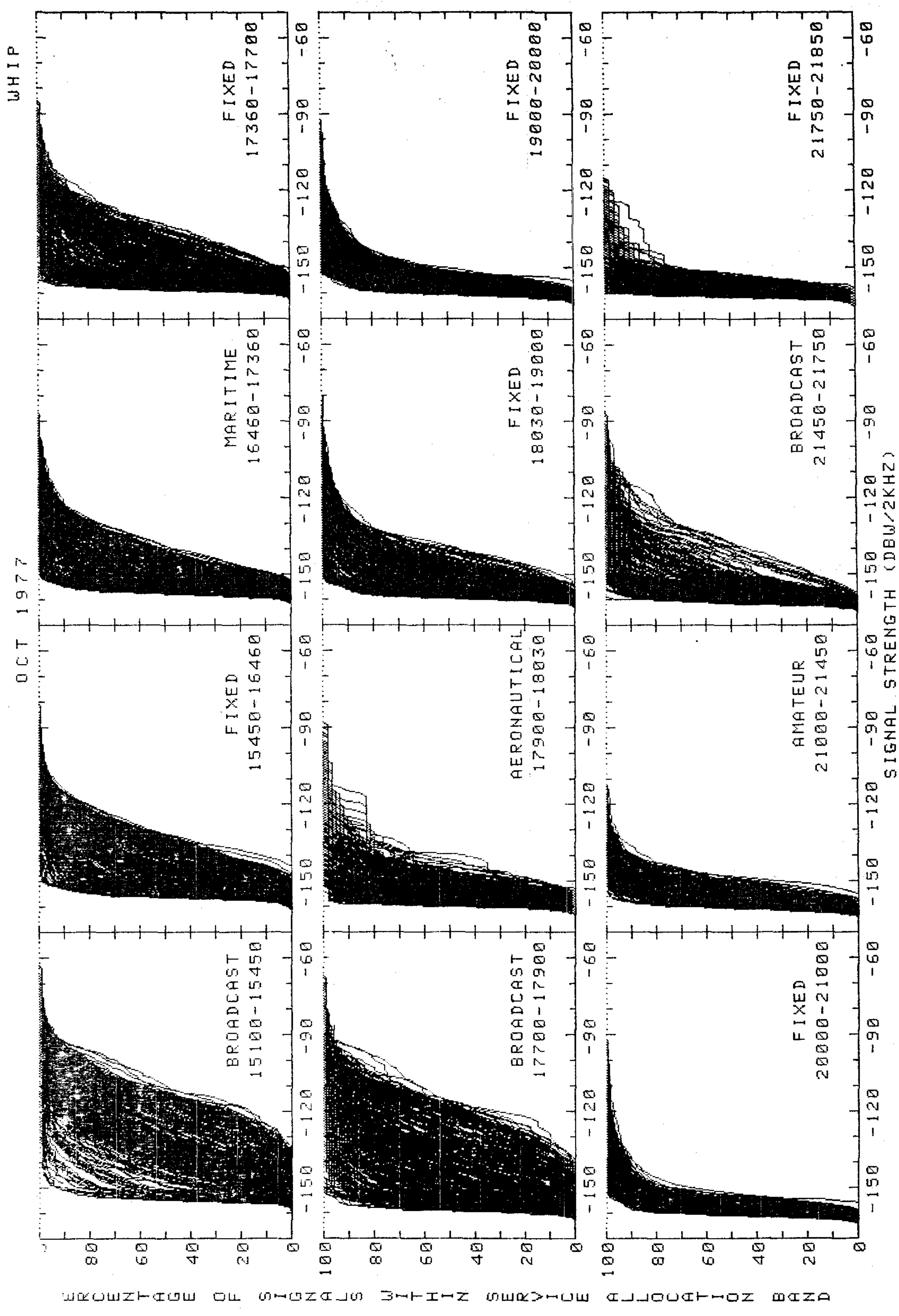

FIGURE 23 SIGNAL DISTRIBUTIONS: 15-20 MHz OCTOBER 1977

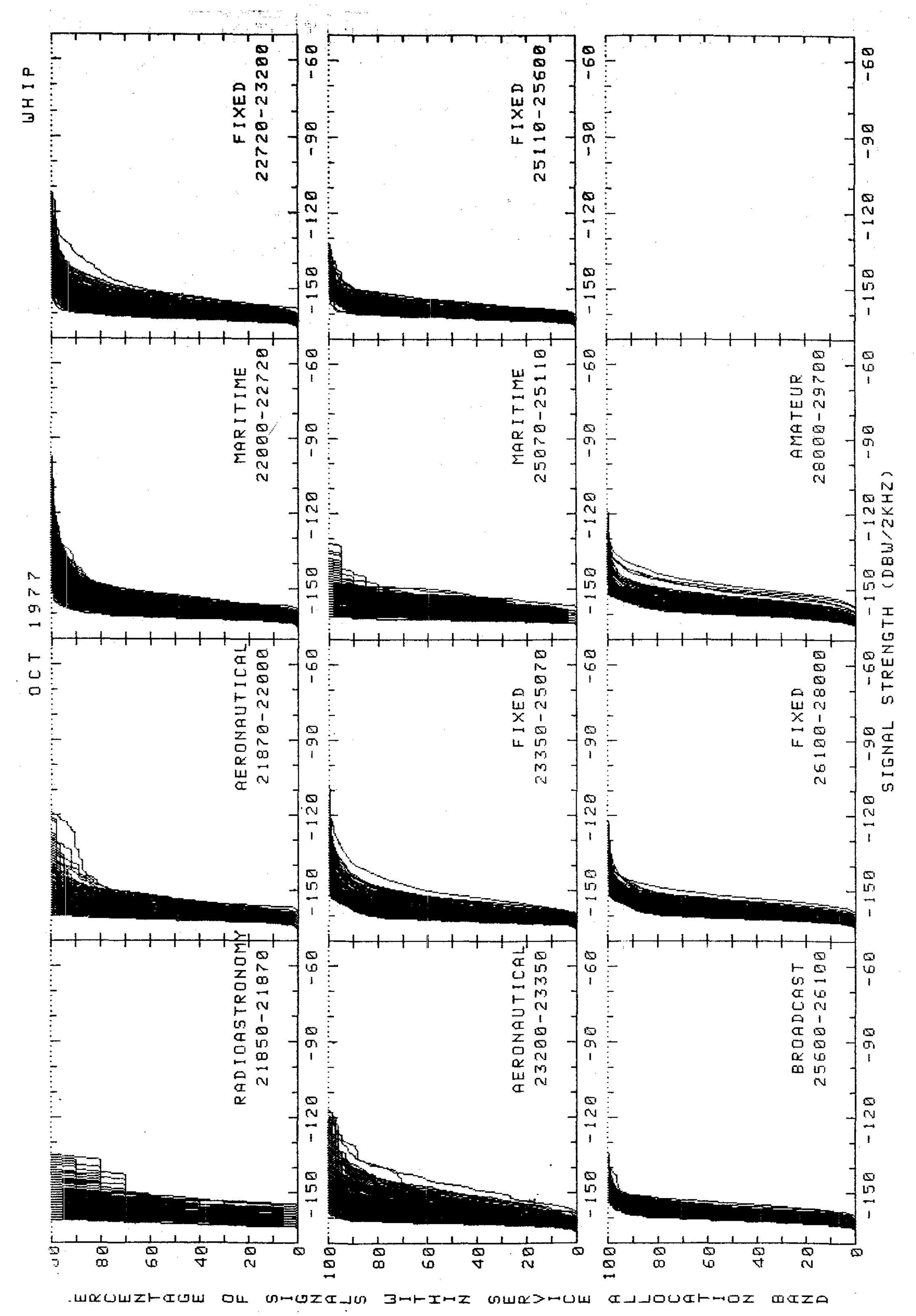

FIGURE 24 SIGNAL DISTRIBUTIONS: 20-30 MHz OCTOBER 1977

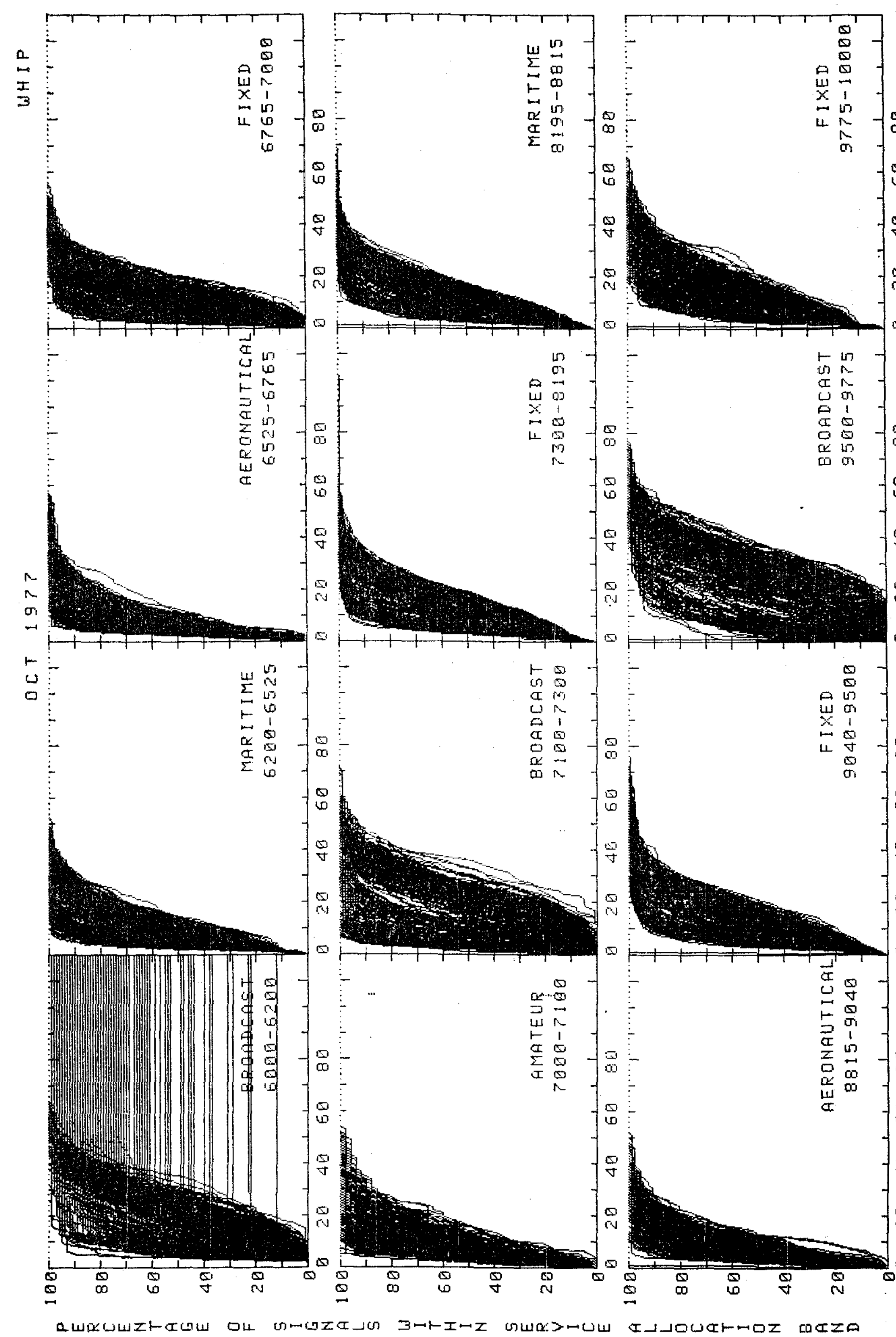

FIGURE 25 DYNAMIC RANGE VARIATIONS: 6-10 MHz OCTOBER 1977

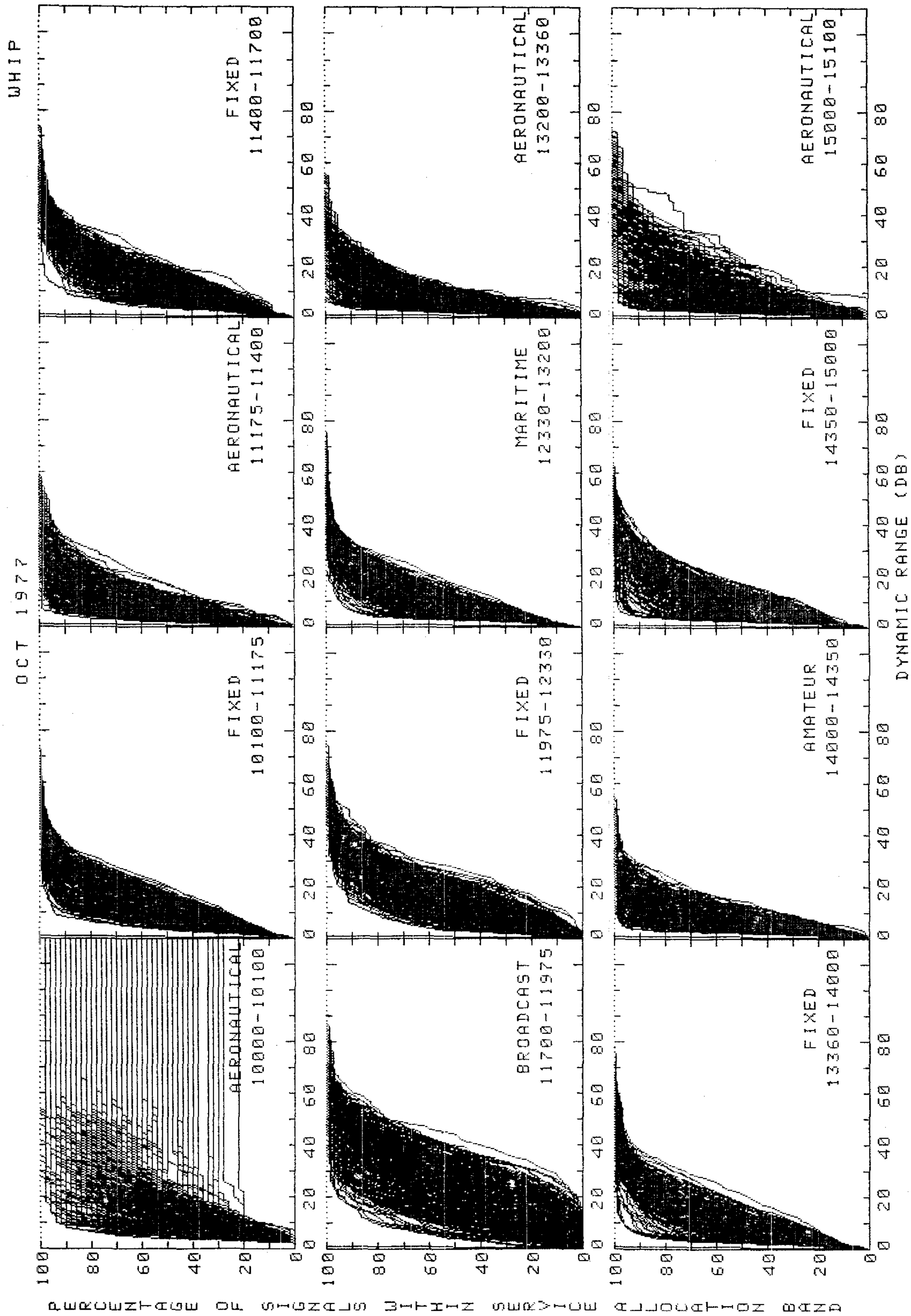

FIGURE 26 DYNAMIC RANGE VARIATIONS: 10-15 MHz OCTOBER 1977

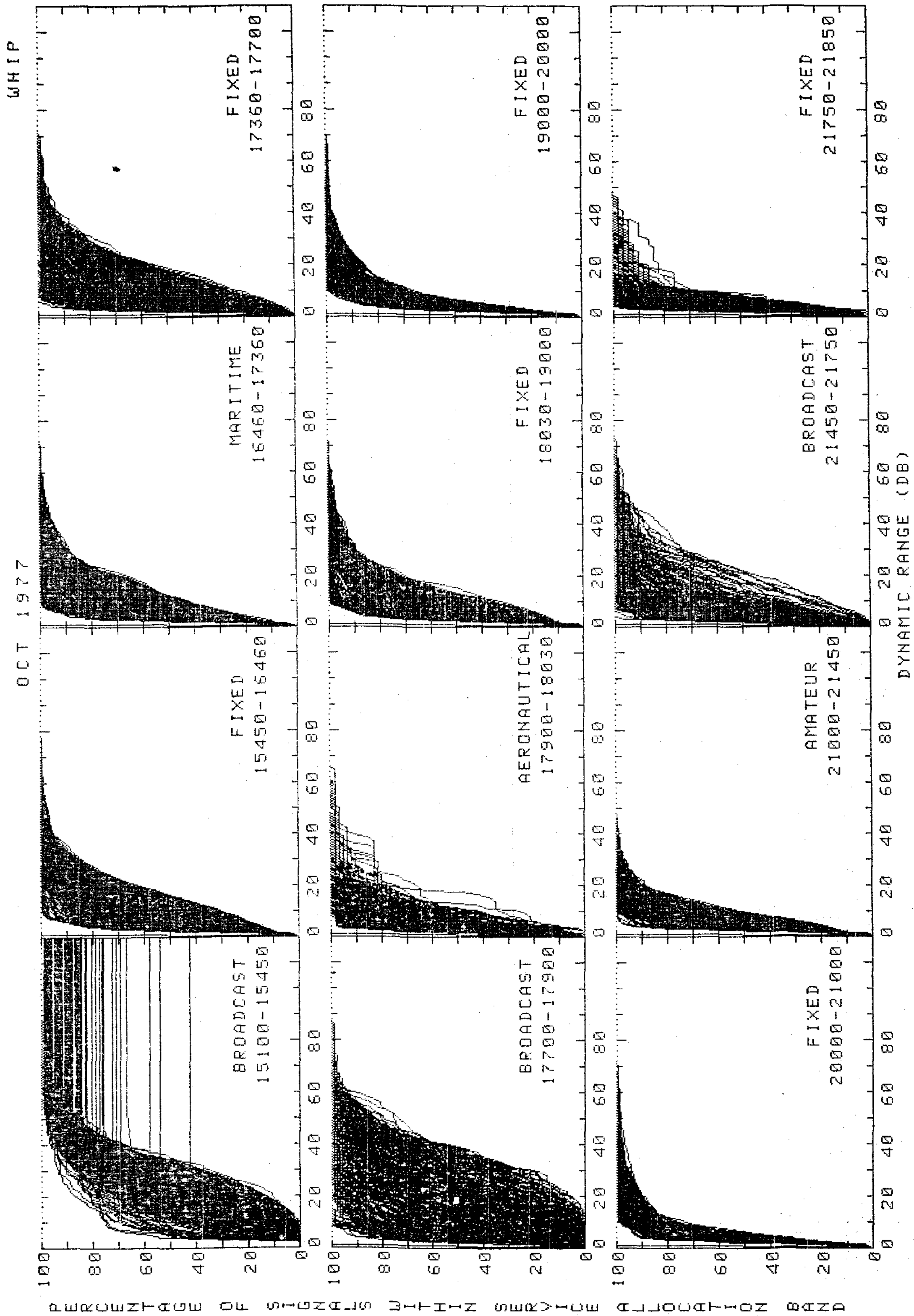

FIGURE 27 DYNAMIC RANGE VARIATIONS: 15-20 MHz OCTOBER 1977

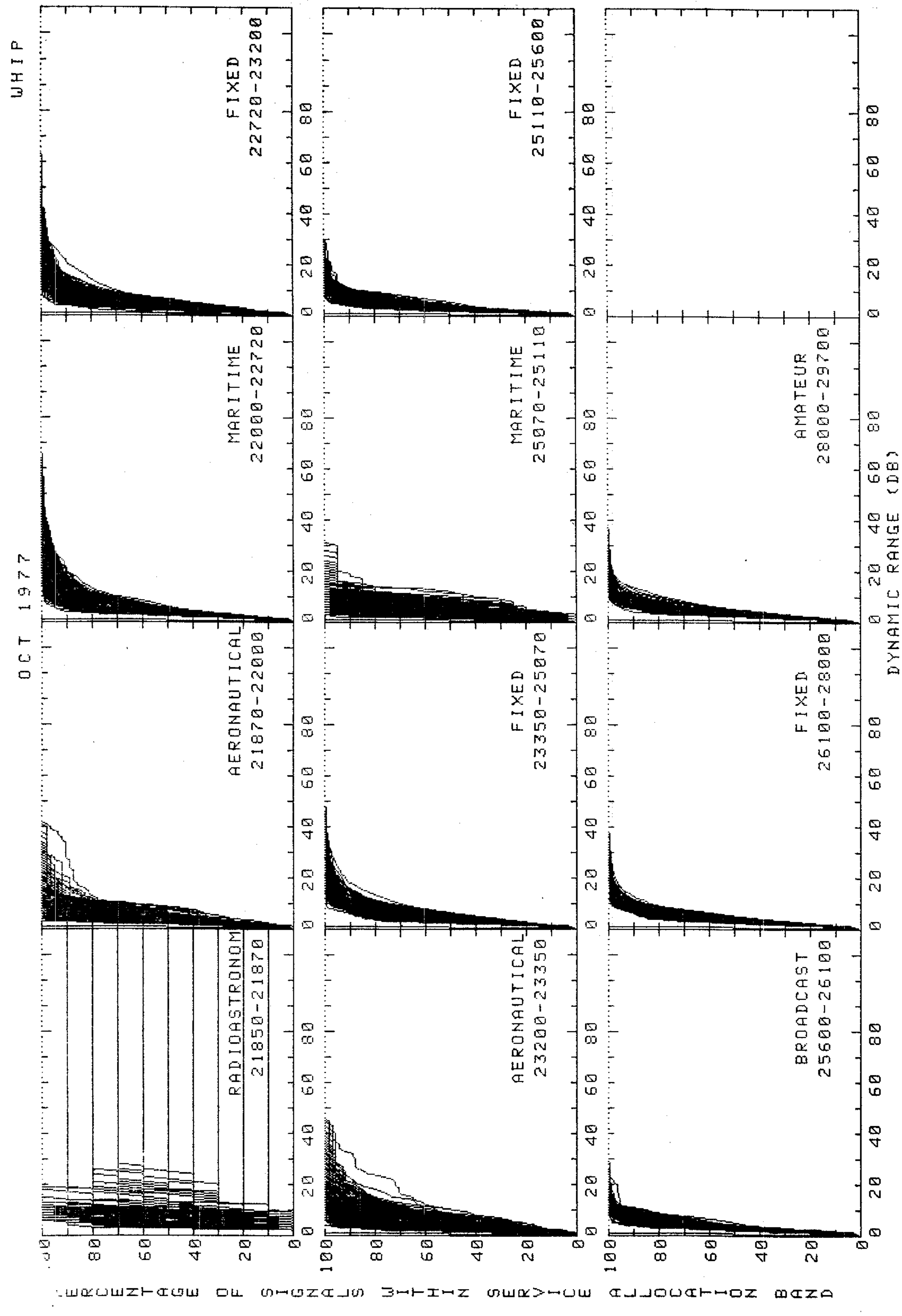

FIGURE 28 DYNAMIC RANGE VARIATIONS: 20-30 MHz OCTOBER 1977

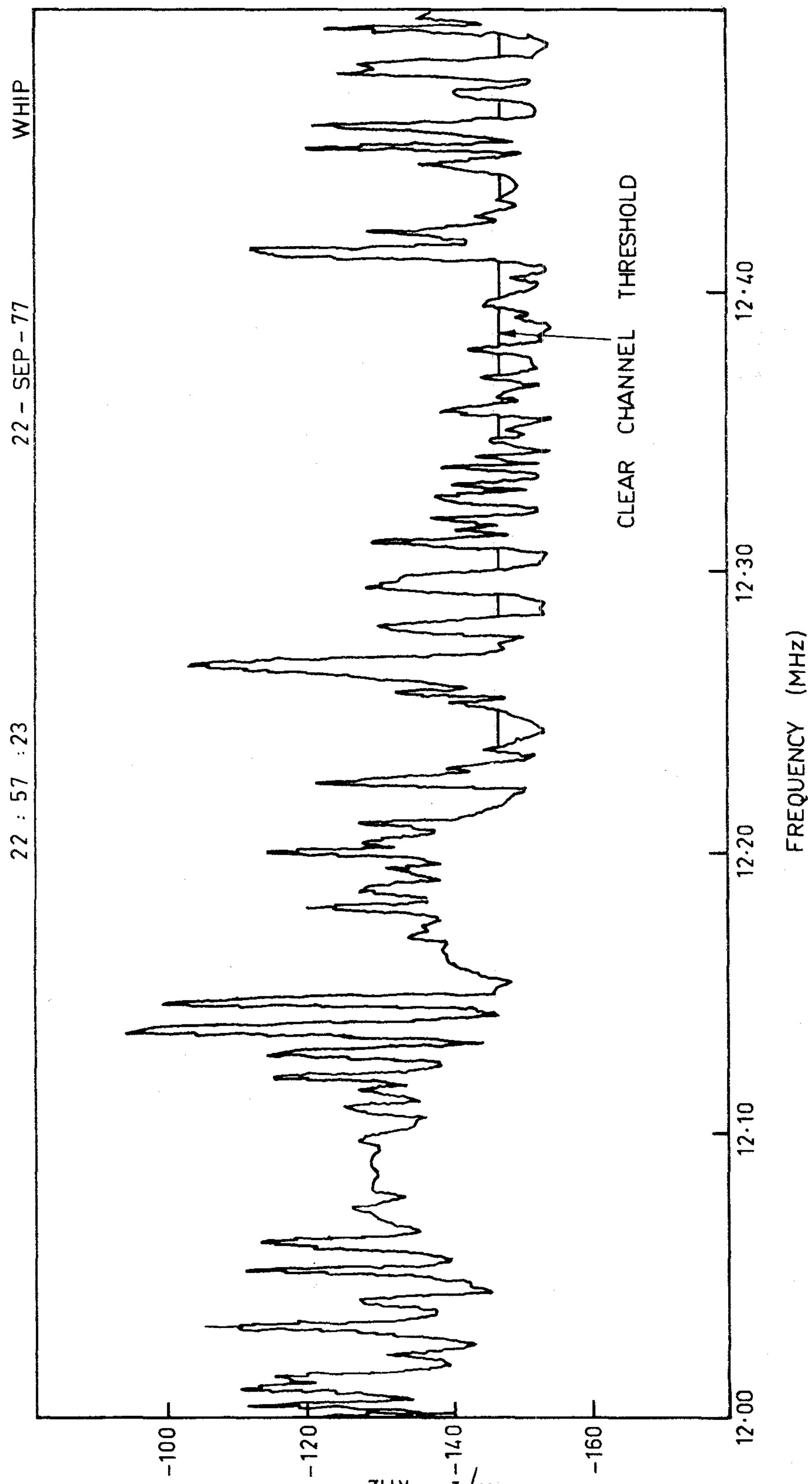

FIGURE 29 PORTION OF THE HF SPECTRUM INDICATING CLEAR CHANNELS

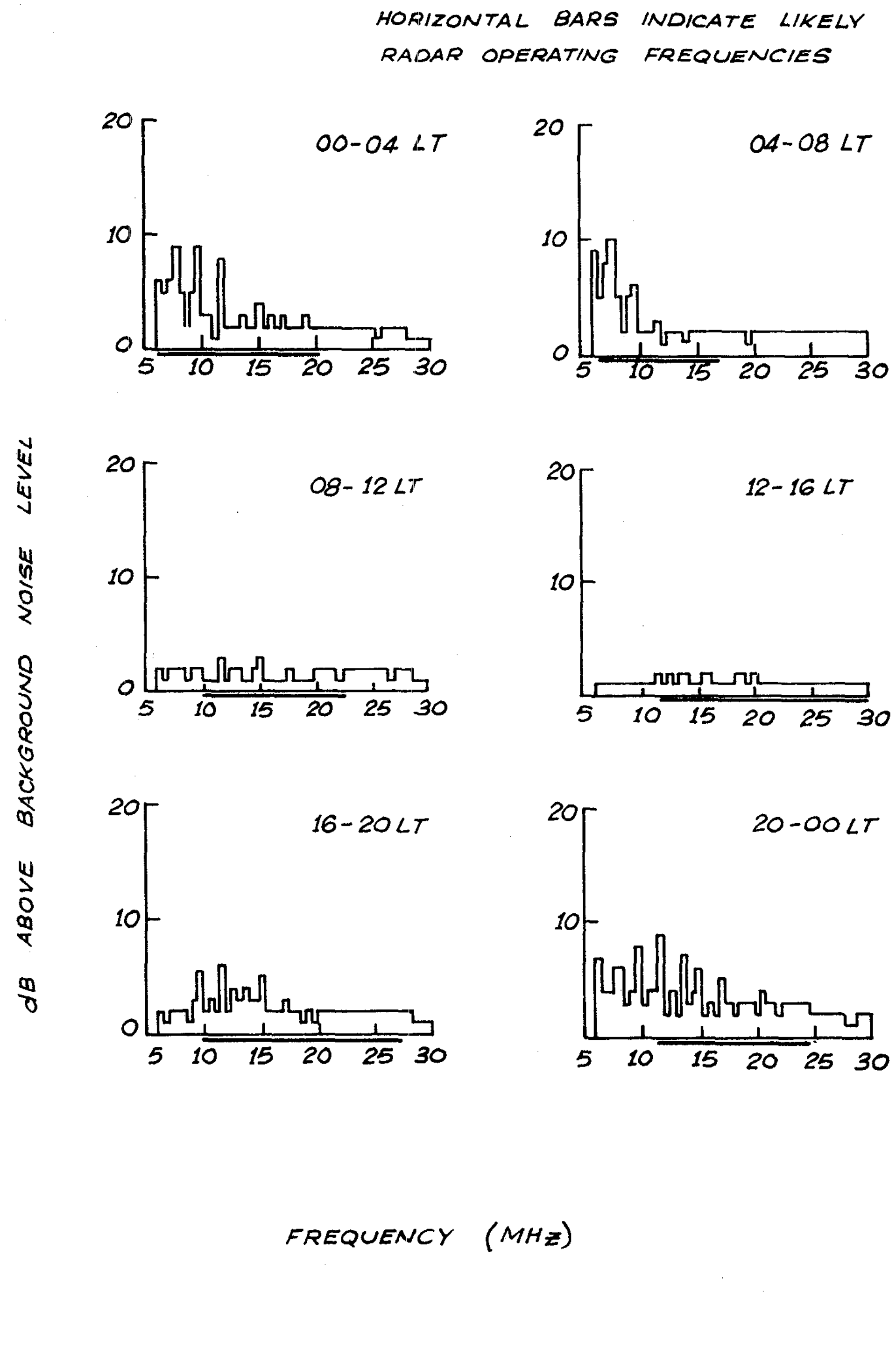

FIGURE 30 10 KHZ CLEAR CHANNEL THRESHOLDS - JANUARY 1978

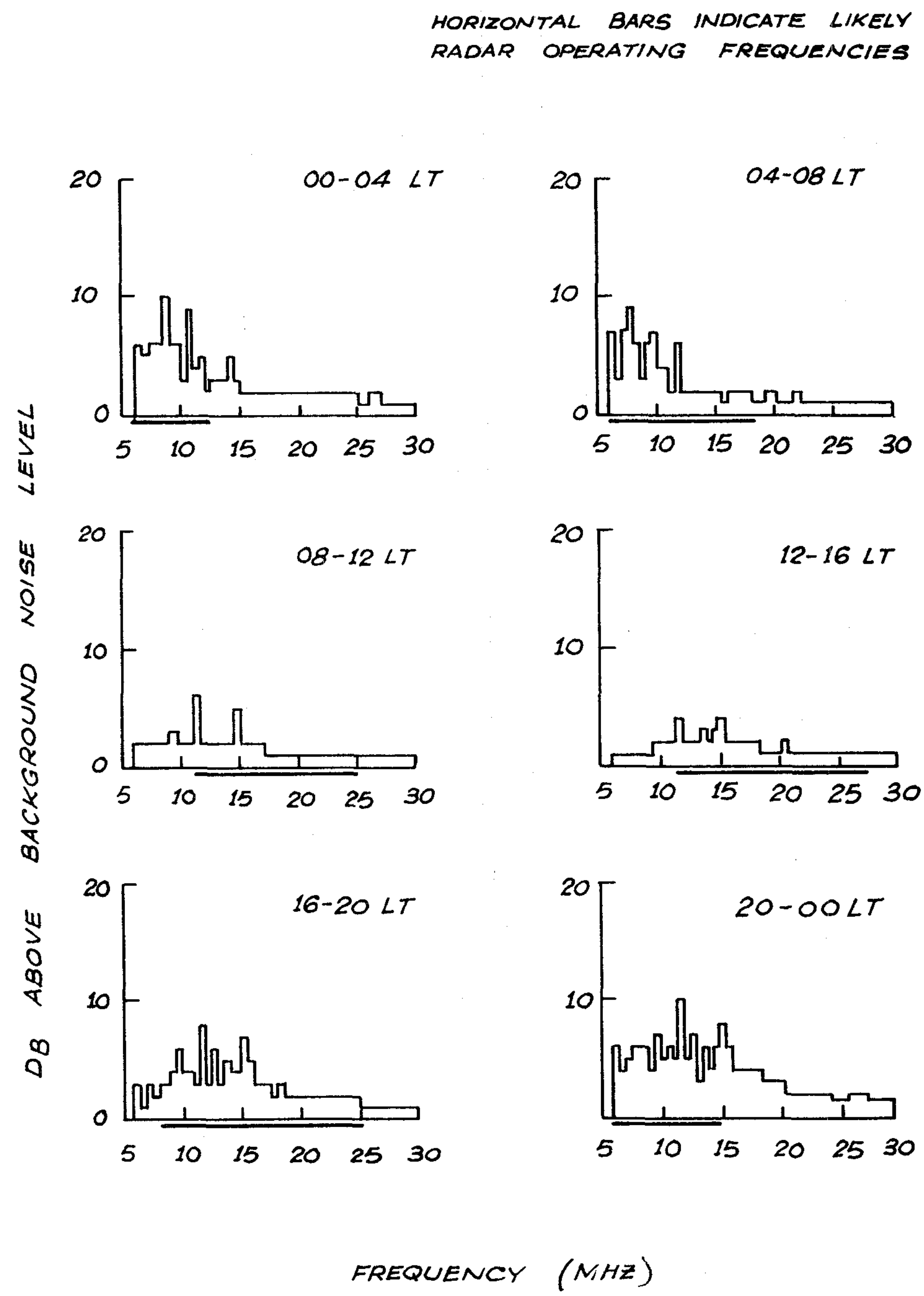

FIGURE 31 10 KHZ CLEAR CHANNEL THRESHOLDS - JULY 1978

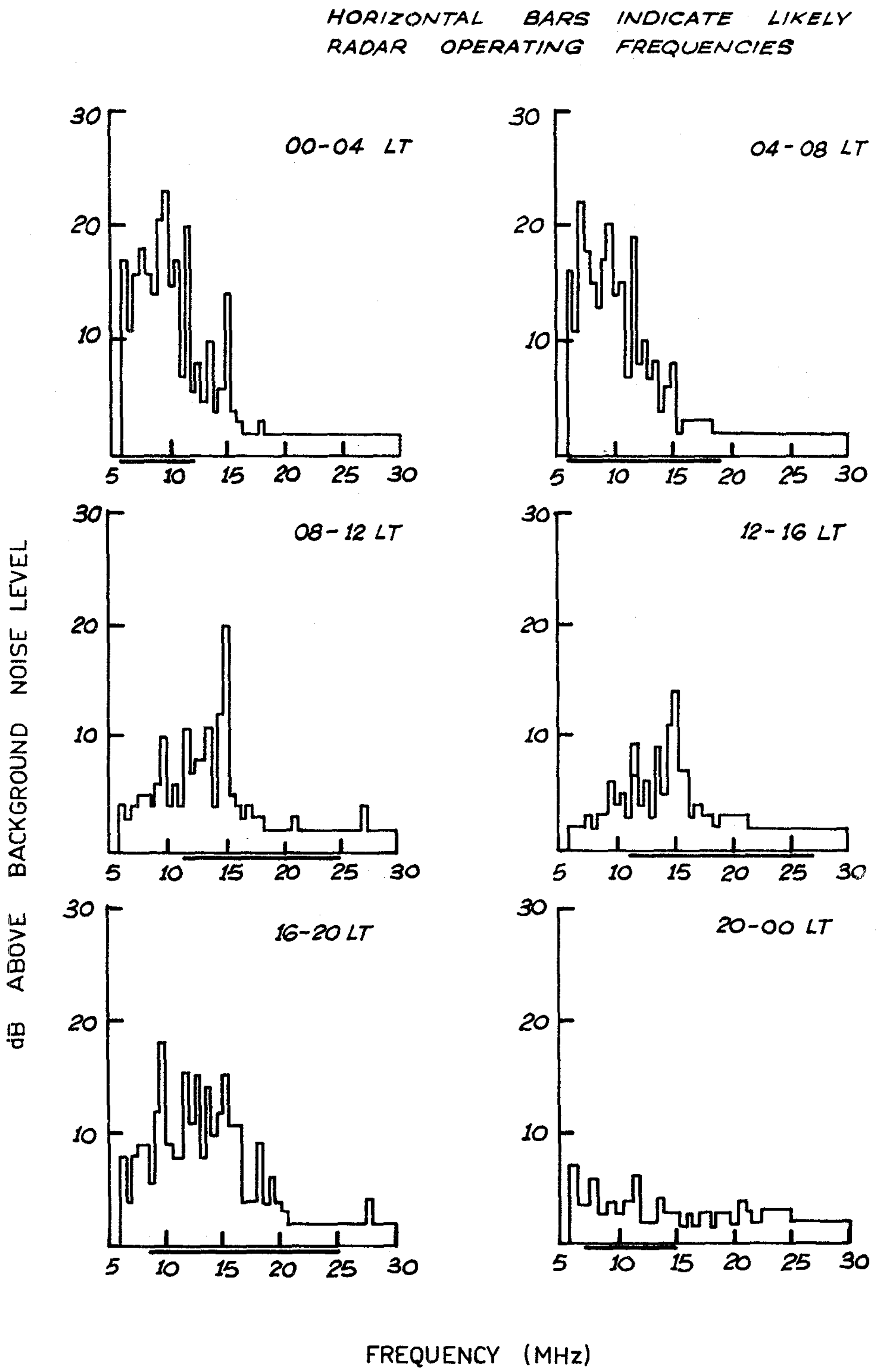

FIGURE 32 20 KHZ CLEAR CHANNEL THRESHOLDS - JULY 1978

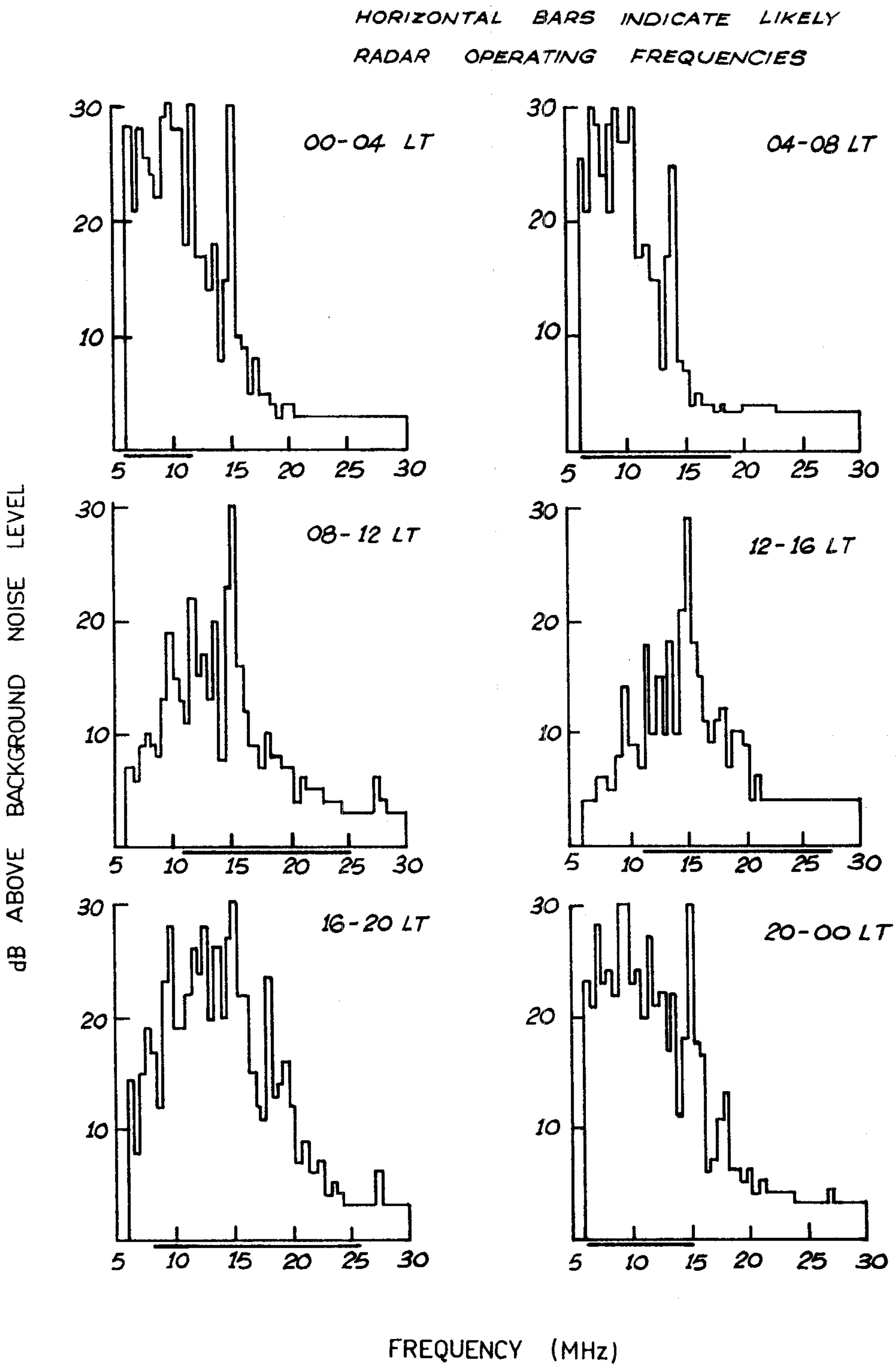

FIGURE 33 40 KHZ CLEAR CHANNEL THRESHOLDS - JULY 1978

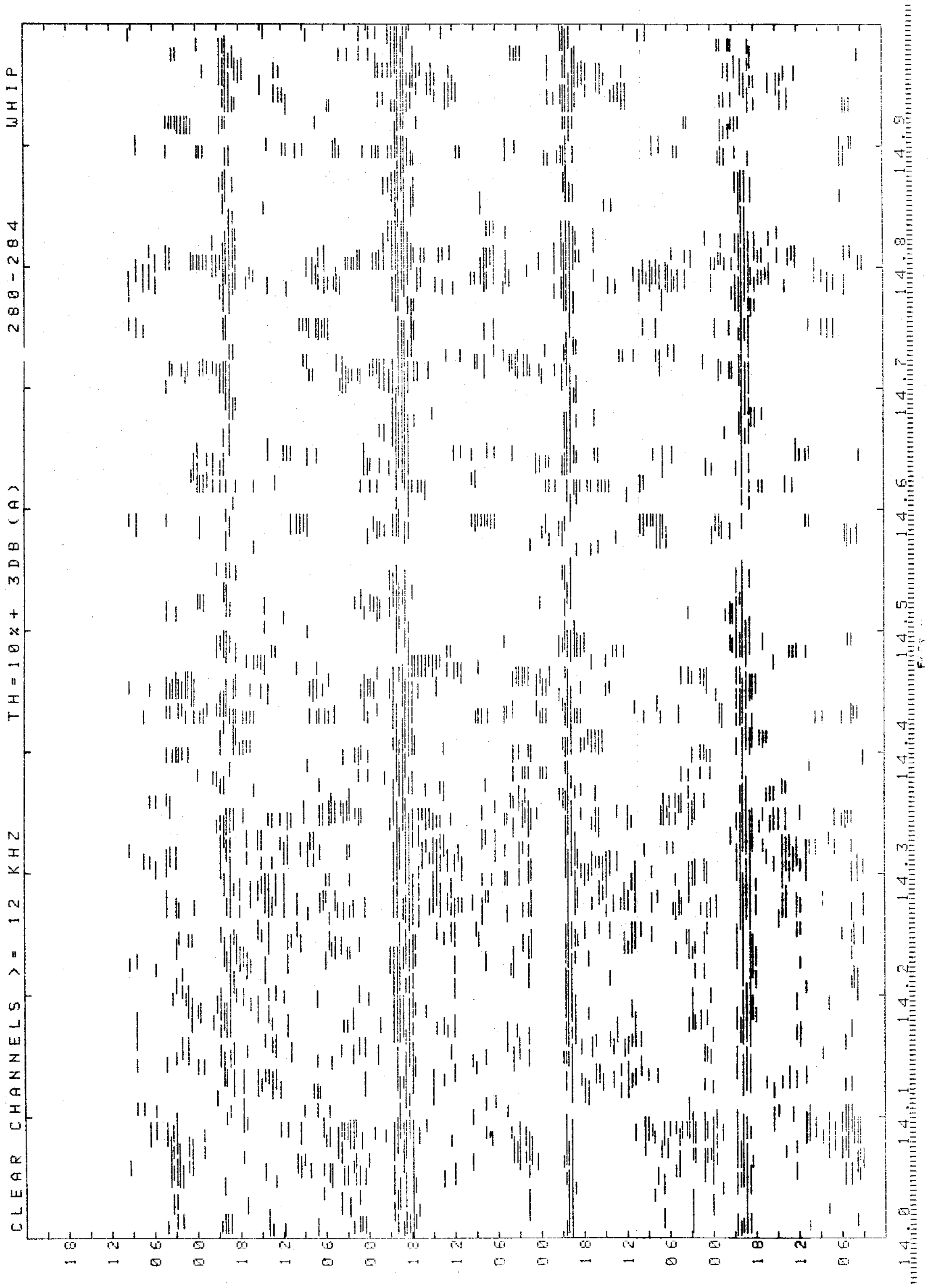

FIGURE 34 DISTRIBUTION OF CLEAR CHANNELS OVER 4 DAYS - 14 MHZ

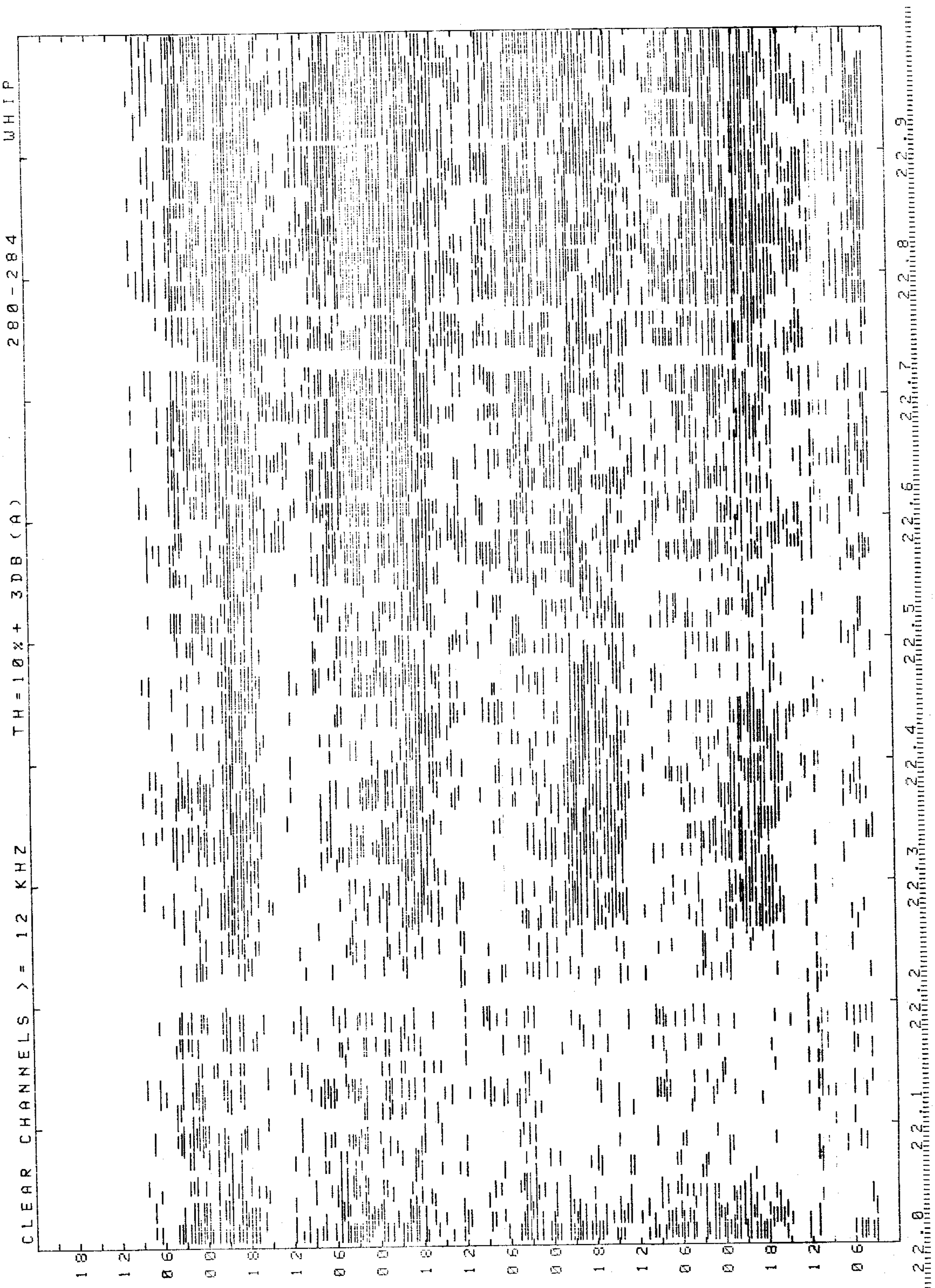

FIGURE 35 DISTRIBUTION OF CLEAR CHANNELS OVER 4 DAYS - 22 MHZ

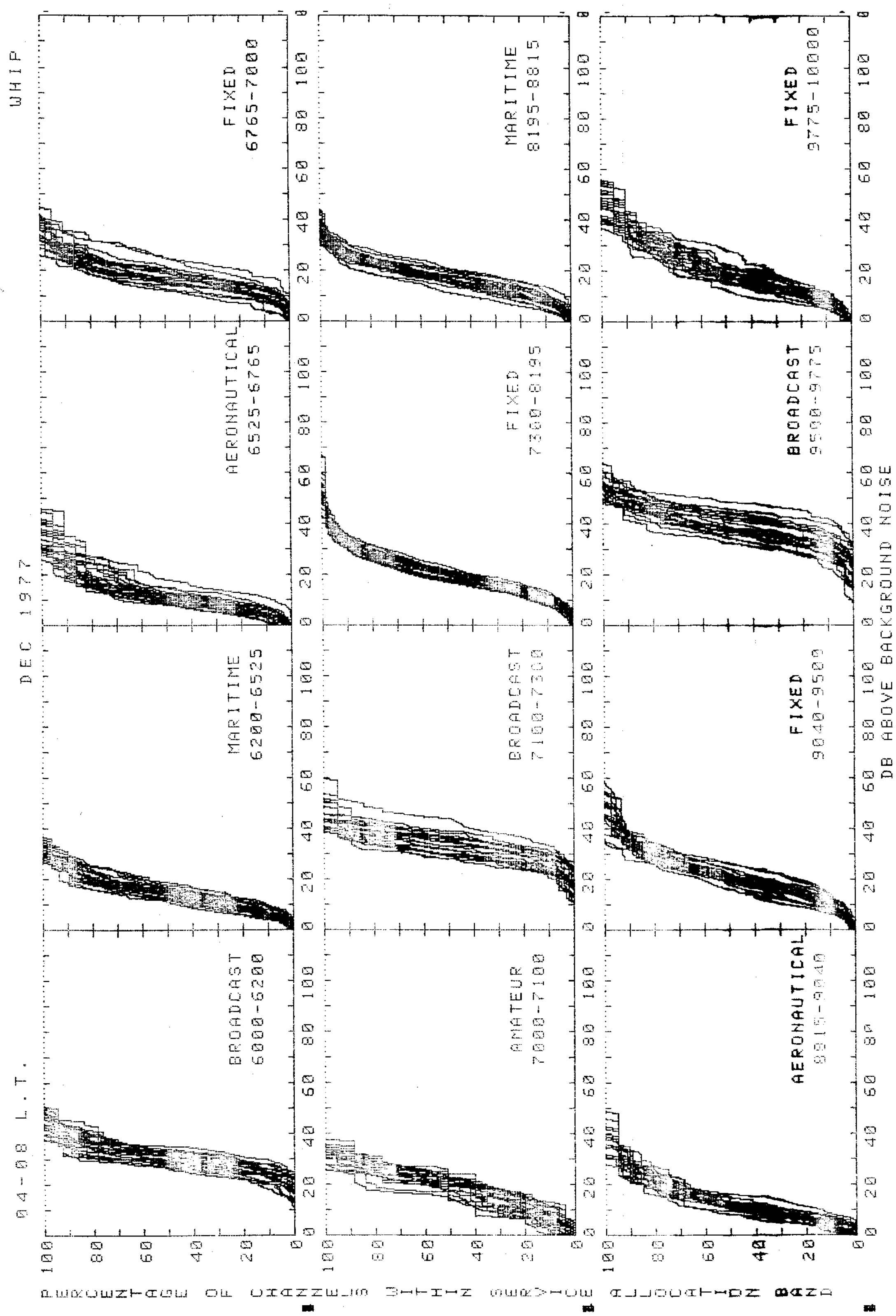

FIGURE 36 MEAN POWER IN A 10 KHZ BANDWIDTH: 6-10 MHZ

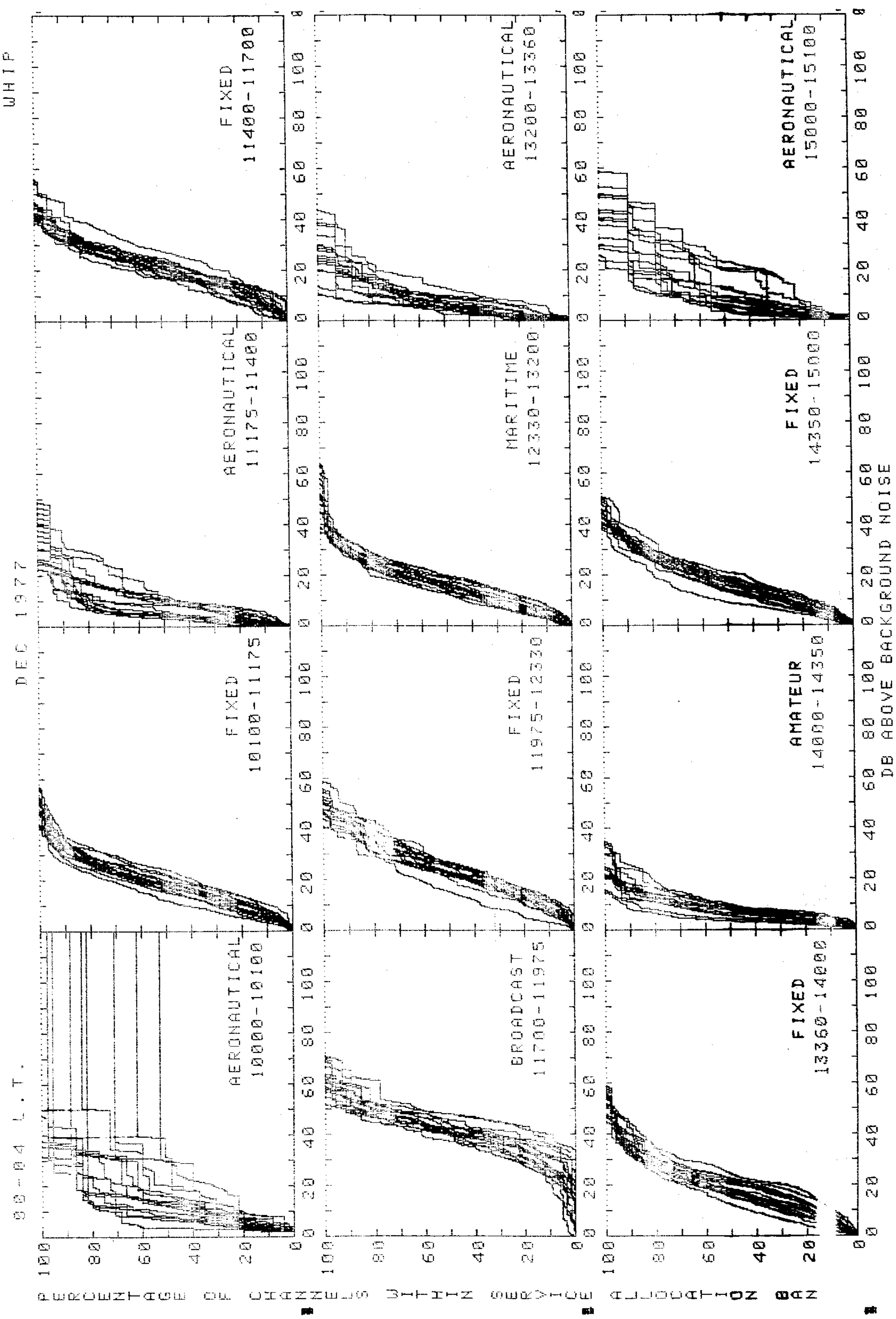

FIGURE 37 MEAN POWER IN A 10 KHZ BANDWIDTH: 10-15 MHZ

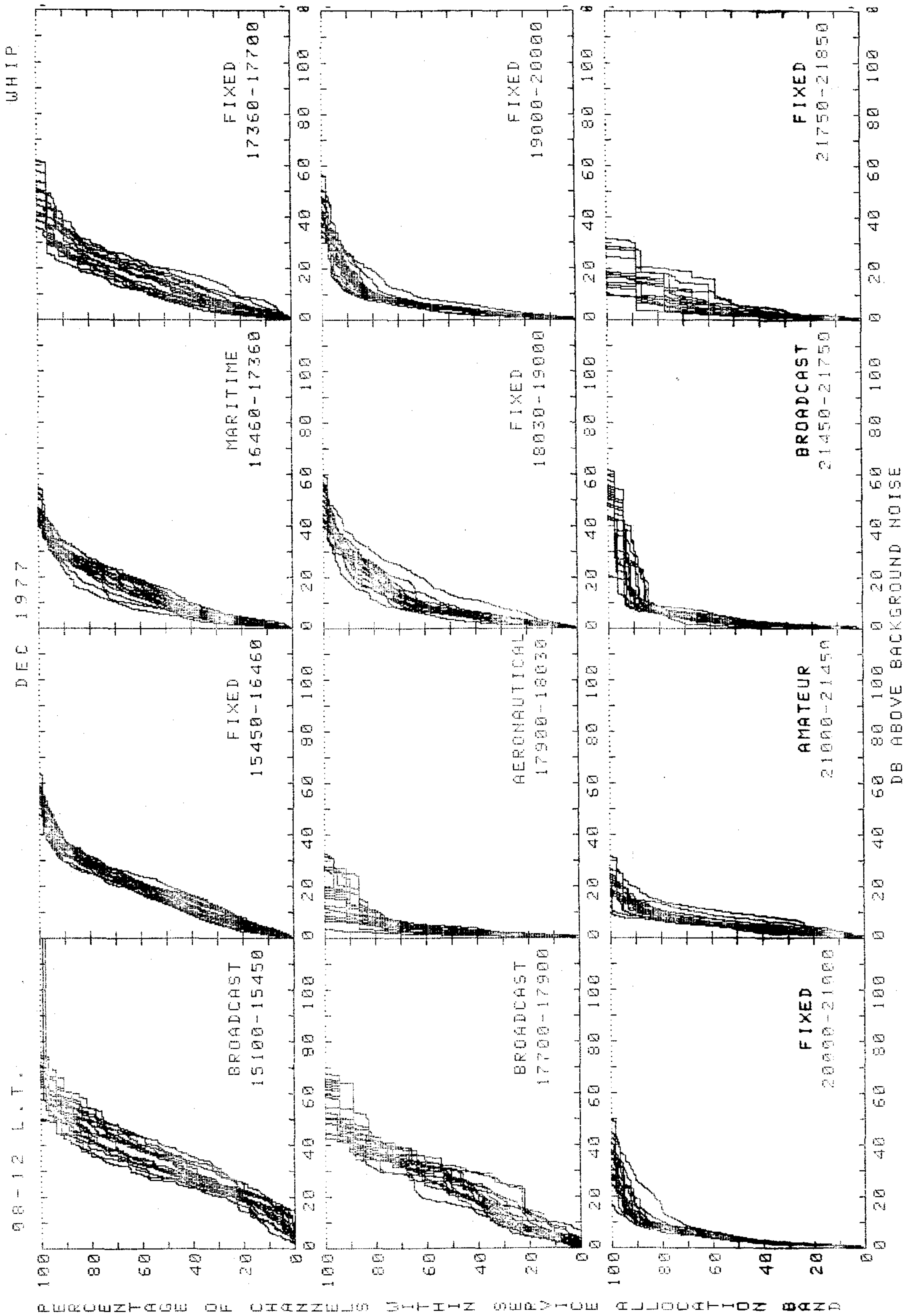

FIGURE 38 MEAN POWER IN A 10 KHZ BANDWIDTH: 15-20 MHZ

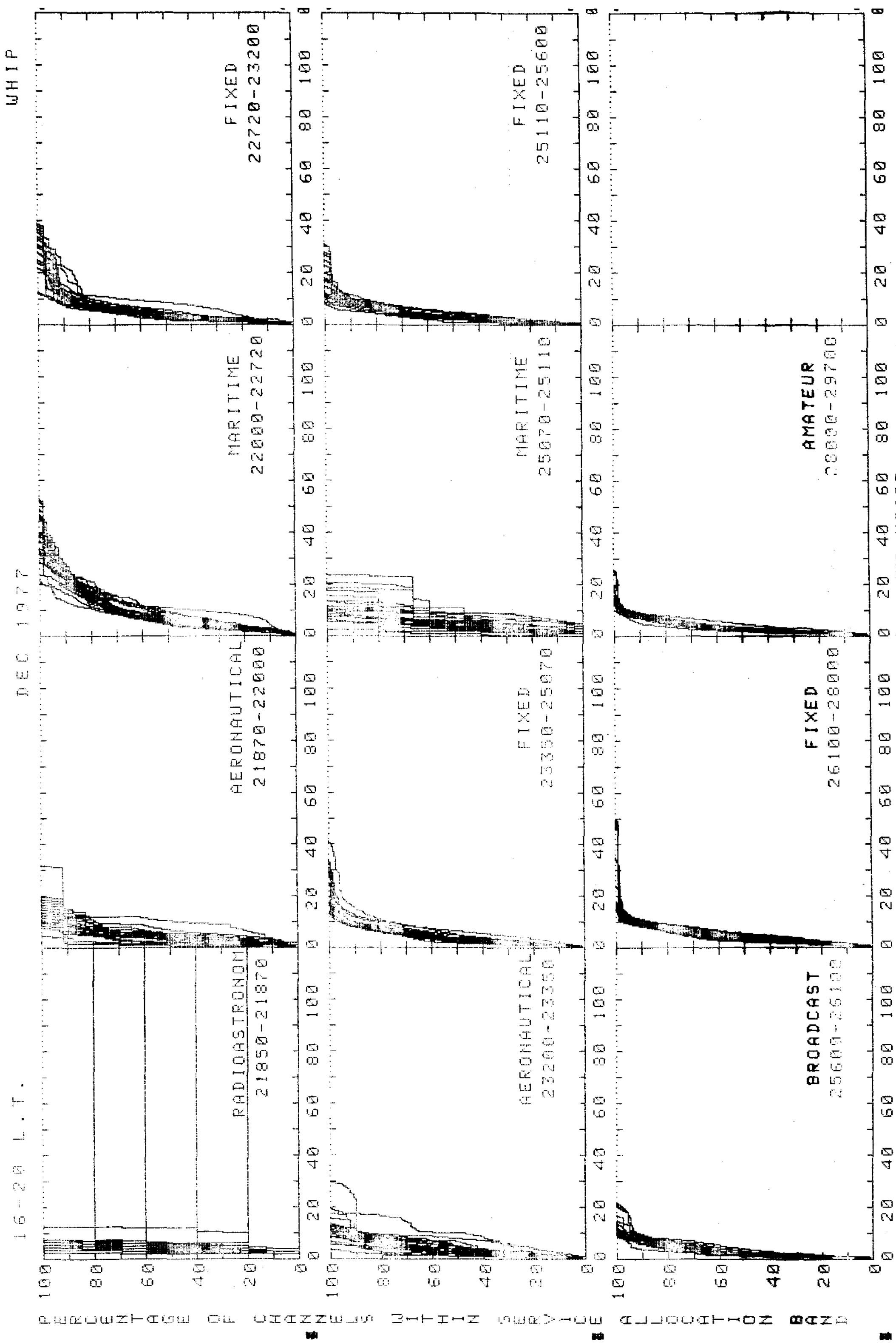

FIGURE 39 MEAN POWER IN A 10 KHZ BANDWIDTH: 20-30 MHZ

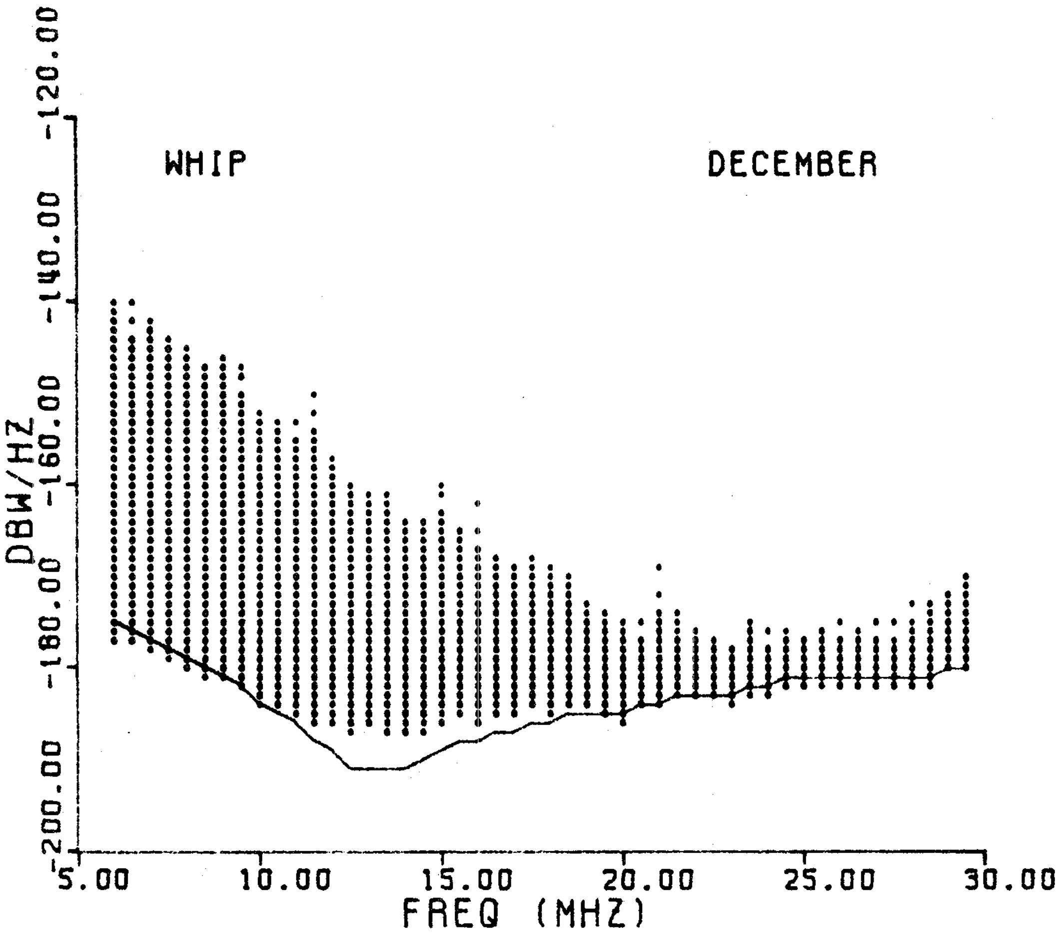

FIGURE 40 (a) RANGE OF NOISE VALUES MEASURED OVER A ONE MONTH PERIOD

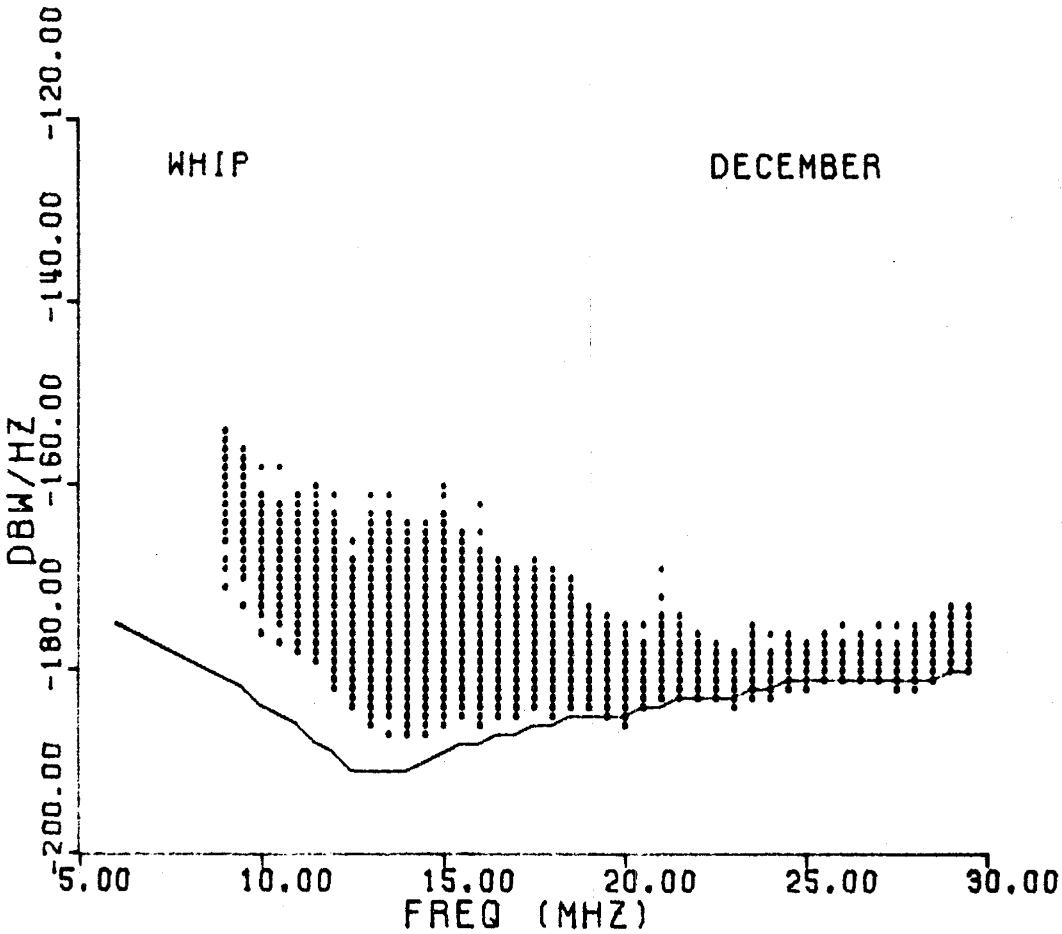

FIGURE 40 (b) RANGE OF NOISE VALUES MEASURED OVER A ONE MONTH PERIOD FOR HOURS OF RADAR OPERATION ONLY

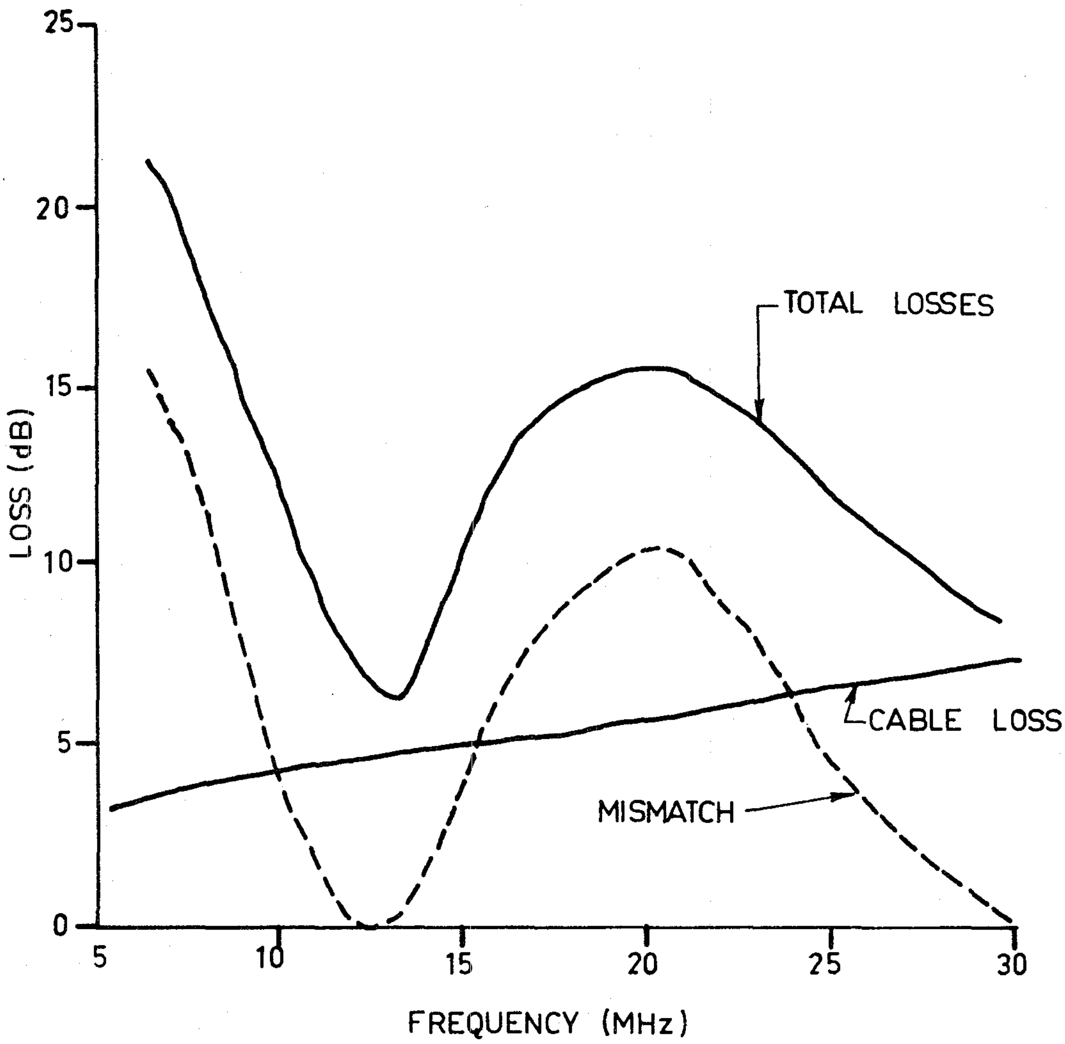

FIGURE 41 LOSSES IN THE MODIFIED SYSTEM

DOCUMENT CONTROL DATA SHEET

Security classification of this page: UNCLASSIFIED

1 DOCUMENT NUMBERS	**2 SECURITY CLASSIFICATION**
AR Number: AR-001-650	a. Complete Document: UNCLASSIFIED Restricted
Series Number: ERL-B134-TR	b. Title in Isolation: Unclassified
Other Numbers:	c. Summary in Isolation: Unclassified

3 TITLE

JINDALEE PAPER NO. 134

4 PERSONAL AUTHOR(S):	**5 DOCUMENT DATE:**
B.D. Ward	November 1983
	6 6.1 TOTAL NUMBER OF PAGES 63
	6.2 NUMBER OF REFERENCES: 9
7 7.1 CORPORATE AUTHOR(S):	**8 REFERENCE NUMBERS**
Electronics Research Laboratory	a. Task: DEF 77/036
	b. Sponsoring Agency: Department of Defence
7.2 DOCUMENT SERIES AND NUMBER	**9 COST CODE:**
Electronics Research Laboratory B134-TR	366965
10 IMPRINT (Publishing organisation)	**11 COMPUTER PROGRAM(S) (Title(s) and language(s))**
Defence Research Centre Salisbury	

12 RELEASE LIMITATIONS (of the document):

Distribution: Approved for Public Release ~~...sts for this document must be referred to Director, E... ...oratory.~~

Security classification of this page: UNCLASSIFIED

Security classification of this page: UNCLASSIFIED

13	ANNOUNCEMENT LIMITATIONS (of the information on these pages):
	~~Not to and Ca~~ ANNOUNCEABLE: to the Public ~~IS Current Awareness Services~~

14	DESCRIPTORS:	15	COSATI CODES:
a. EJC Thesaurus Terms	HF Radar Atmospheric noise		-
b. Non-Thesaurus Terms			

16	SUMMARY OR ABSTRACT: (if this is security classified, the announcement of this report will be similarly classified)
	-

Security classification of this page: UNCLASSIFIED